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Technical Memorandum

Date: September 23, 2005

To: Ryan Baker, Smith Williams Consultants, Inc.

cc:

From: Troy Thompson/ Blair Hurst

Project: Rock Creek and Big Hurrah Mine Sites

Re: Climate Data

The objective of this memo is to provide an overview of available climate data and the methodology used to quantify meteorological data to be used for facilities design at the proposed Rock Creek and Big Hurrah mine sites. Selected data and all results for each site are provided in the text. Supporting data and calculation methods are presented in **Appendices A-G**.

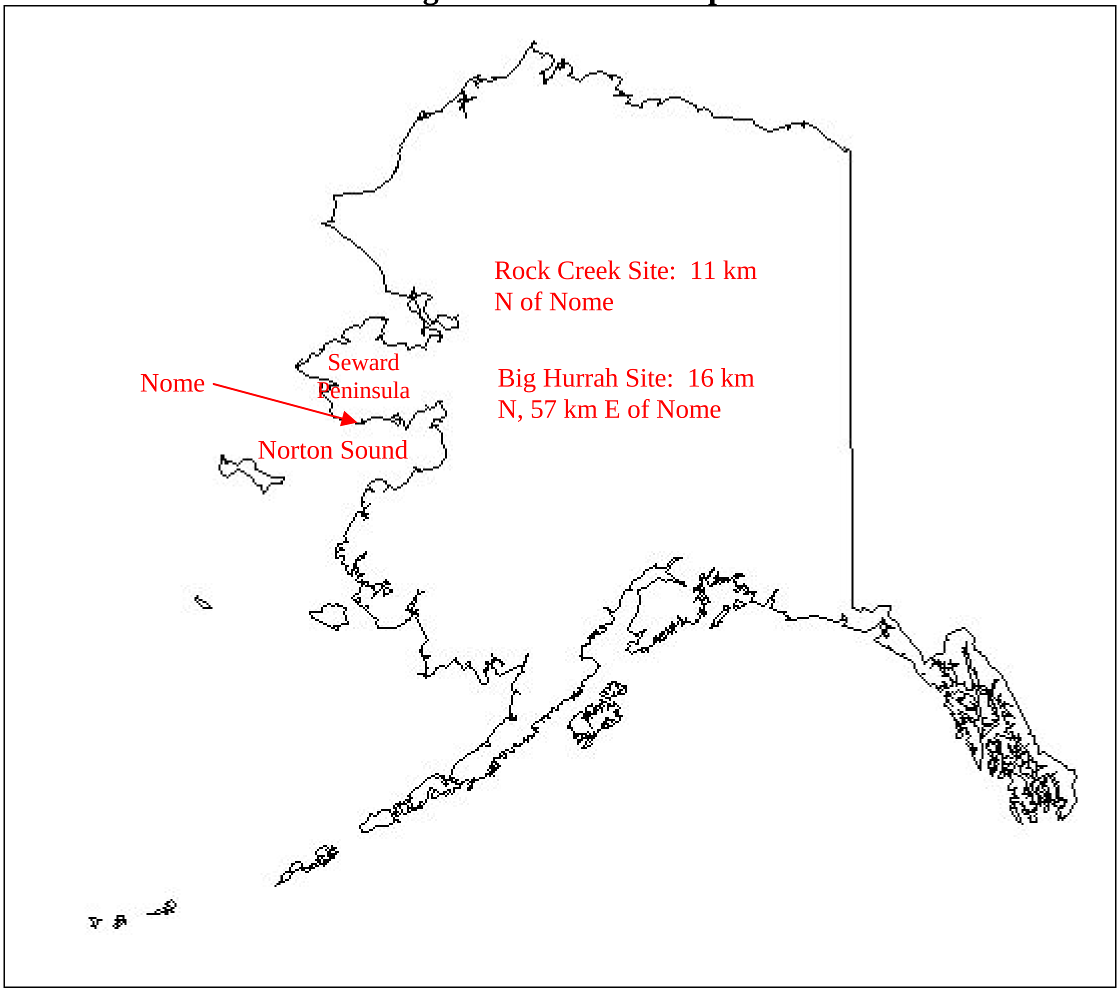
1.0 Introduction and Site Description

The proposed Rock Creek site is located about 11 km due north of Nome on the southern coast of Alaska's Seward Peninsula at 64º 37' N latitude and 165º 26' W longitude. The site is situated along the upper reaches of Rock Creek, a headwater stream, at an average elevation of 115 m above mean sea level. The drainage area at the site is approximately 4 km^2. Rock Creek is a tributary to the Snake River, which drains into Norton Sound at Nome.

The proposed Big Hurrah site is located about 16 km north, and 57 km east of Nome at 64º 38.5' N latitude and 164º 14' W longitude. The site is situated on the lower reach of the headwater stream Little Hurrah Creek, at the confluence with Big Hurrah Creek. The drainage area at the Big Hurrah site is approximately 3 km^2, and the average elevation of the site is 90 m above mean sea level. Big Hurrah Creek is a tributary to the Solomon River, which drains into Norton Sound 47 km east of Nome.

Both sites are characterized by shrubs and tundra on gently rolling landscapes below steeper sparsely vegetated peaks. A location map is shown in **Figure 1**.

Figure 1. Location Map



2.0 Climatological Data and Methods

Climate data and a brief description of applied methods for quantifying precipitation, evaporation, evapotranspiration, and snow sublimation are provided in the following sections. Precipitation data for both the Rock Creek and Big Hurrah sites were obtained from the Oregon State Spatial Climate Analysis Service, US Weather Bureau Precipitation Atlases, and the Western Regional Climate Center. Average monthly precipitation, short term storm totals, and probable maximum precipitation values are presented in Section 2.1.

Detailed hourly climate data including wind speed, temperature, relative humidity, barometric pressure, and solar radiation were collected in 2004 at the Rock Creek site by the Hoefler Consulting Group as a part of the Rock Creek Air Monitoring Program. These data can be found in four quarterly data reports prepared by the Hoefler Consulting Group for the Rock Creek Ambient Air and Meteorological Monitoring Project. Comparable data has not been collected at the Big Hurrah site. Average monthly wind speed, temperature, relative humidity, barometric pressure, and solar radiation values at the Rock Creek Site are presented in Section 2.2.

Evaporation, evapotranspiration, and snow sublimation values for the Rock Creek site, calculated by ERC using data collected by the Hoefler Consulting Group and standard equations, are presented in Sections 2.3- 2.5. Snow melt is briefly discussed in Section 2.6.

2.1 Precipitation

2.1.1 Average Monthly Data

State-wide average precipitation data for each month for the period between 1961 and 1990 are available through the Oregon State Spatial Climate Analysis Service (SCAS). This GIS-based data set was assembled into maps of monthly average precipitation by the Institute of Artic and Alpine Research at the University of Colorado at Boulder. These maps were used to quantify average monthly precipitation at Nome, the Rock Creek site, and the Big Hurrah site. From this analysis, annual total precipitation at Nome was determined to be 391.5 mm. Annual total precipitation at the Rock Creek and Big Hurrah sites was determined to be 478.0 and 540.0 mm, respectively. All monthly and annual values are presented in **Table 1**. Average monthly precipitation maps are presented in **Appendix A**.

Table 1.
Average Monthly Precipitation
(SCAS 1961-1990)

Month	Nome (mm)	Rock Creek (mm)	Big Hurrah (mm)
January	24.5	27.0	37.0
February	16.0	23.0	28.0
March	18.0	20.0	26.0
April	17.0	19.0	21.0
May	16.0	18.0	21.0
June	33.0	39.5	37.0
July	54.0	74.0	80.0
August	74.0	85.5	97.0
September	57.0	74.0	91.0
October	37.0	42.0	40.0
November	25.0	31.0	32.0
December	20.0	25.0	30.0
Annual Total	391.5	478.0	540.0

The Rock Creek and the Big Hurrah site annual precipitation totals are 22% and 37% greater than the totals for Nome, respectively. It should be noted that Water Management Consultants presented a comparison of the total precipitation values at the Nome Municipal Airport with those collected at the Rock Creek site for a total of four months in Table 2.2 of the Rock Creek Mine Project Water Management Report dated May 2005. Data presented indicate that the total precipitation at the Rock Creek site is 25% greater than at Nome for that time, consistent with results shown in **Table 1**.

In order to compare the values presented in **Table 1** with validated results, ERC obtained average monthly precipitation values for the Nome Municipal Airport, which are available through the Western Regional Climate Center (WRCC). The WRCC maintains an online database that includes average monthly precipitation totals for the period between 1948 and 2004. For this data set, the normal precipitation is the arithmetic mean for each month over the period of record, adjusted as necessary, and includes the liquid water equivalent of snowfall.

The average monthly precipitation values in Nome for the period between 1961 and 1990 are presented in **Table 2** to confirm the validity of the results presented in **Table 1**. This period of record was chosen as it is identical to the period of record used by the SCAS to produce data presented in **Table 1**. It is of note that there is a 3% difference between the annual total precipitation values at Nome presented in **Tables 1** and **2**, which validates the approach used by ERC.

Table 2.
Average Monthly Nome Precipitation
(WRCC 1961-1990)

Month	Precipitation (mm)
January	21.3
February	15.5
March	15.0
April	16.5
May	18.0
June	27.9
July	53.8
August	70.6
September	59.7
October	36.6
November	24.9
December	21.1
Annual Total	380.5

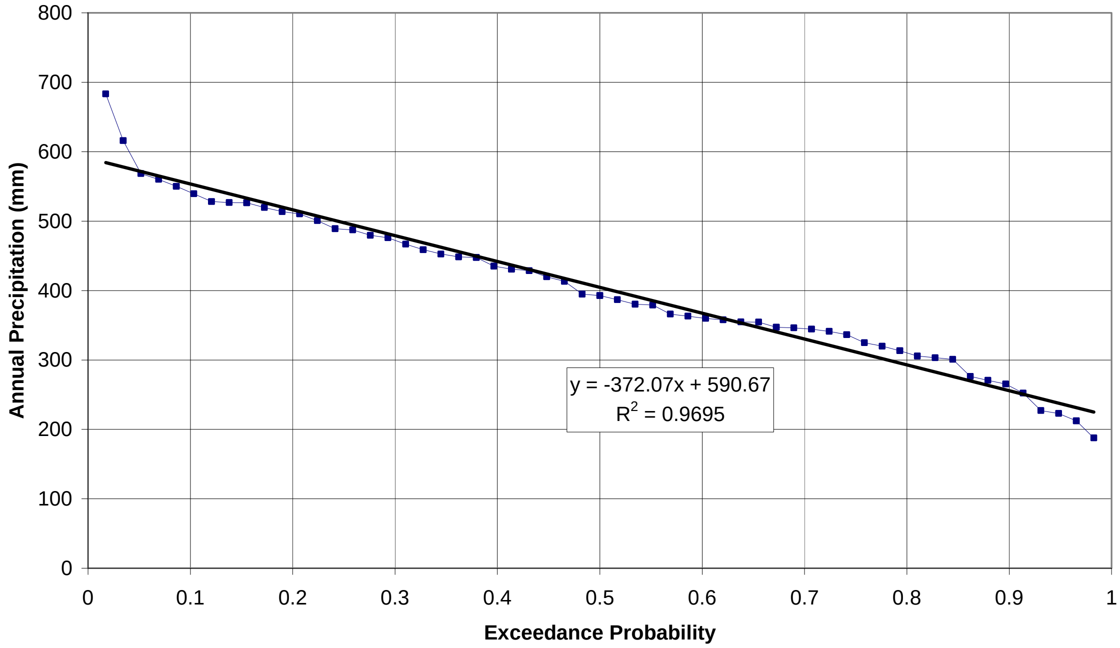
Based on the validity of the Nome precipitation data presented in **Table 1**, ERC considered the precipitation values for the Rock Creek and Big Hurrah sites to be reasonable. ERC used the calculated percentages of total precipitation at the Rock Creek and Big Hurrah sites (22% and 37% greater than Nome, respectively) with the average monthly precipitation totals at Nome for the full period of record between 1948 and 2004 published by the WRCC to determine the average monthly precipitation at the Rock Creek and Big Hurrah sites for the same period. Results are shown in **Table 3**.

Table 3.
Average Monthly Precipitation
(WRCC 1948-2004)

Month	Nome (mm)	Calculated Rock Creek (mm)	Calculated Big Hurrah (mm)
January	22.2	27.1	30.5
February	17.3	21.1	23.7
March	15.2	18.6	20.9
April	17.6	21.5	24.1
May	18.0	22.0	24.7
June	26.5	32.4	36.4
July	54.2	66.1	74.2
August	83.2	101.6	114.1
September	61.2	74.7	83.9
October	37.2	45.4	51.0
November	28.3	34.5	38.8
December	22.4	27.3	30.6
Annual Total	404.6	493.7	554.4

Annual precipitation resulting from extreme wet and dry years was calculated based on the 57 years of available monthly Nome precipitation data. Annual totals were plotted using the Weibull formula and are shown on **Figure 2**. The wettest and driest years of record totaled 683 mm and 188 mm of precipitation, respectively. Based on the plot below, the high value is above the trend line and may slightly overestimate a 1% wet year, and the low value is below the trend line and may slightly underestimate a 1% drought. The values of 683 mm and 188 mm were used as the design values. Factoring in the difference between predicted precipitation at the sites and Nome, the 1% wet year was estimated to be 833 mm and 936 at the Rock Creek and Big Hurrah sites, respectively. One percent annual drought rainfall was estimated to be 229 mm at Rock Creek and 258 mm at Big Hurrah.

Figure 2.
Nome Annual Precipitation Exceedance Probability (1948-2004)



2.1.2 Storm Data

Data for short term duration storms at the Rock Creek and Big Hurrah sites were collected from the U.S. Department of Commerce Weather Bureau Technical Paper 47: Probable Maximum Precipitation and Rainfall-Frequency Data for Alaska. This report is available through the Western Regional Climate Center and presents state-wide rainfall isohyetal maps for storm durations up to 24 hours and return periods from 1 to 100 years. Rainfall intensity-duration-frequency (IDF) curves for both sites were created by ERC based on these data and are shown graphically in **Figures 3** and **4**. Numerical values for the IDF curves are provided in **Table 4**. Note that rainfall intensity values for both sites are the same with the exception of storms with a 50- and 100-year return period. Isohyetal maps are presented in **Appendix B**.

Figure 3.
Rock Creek IDF Curve

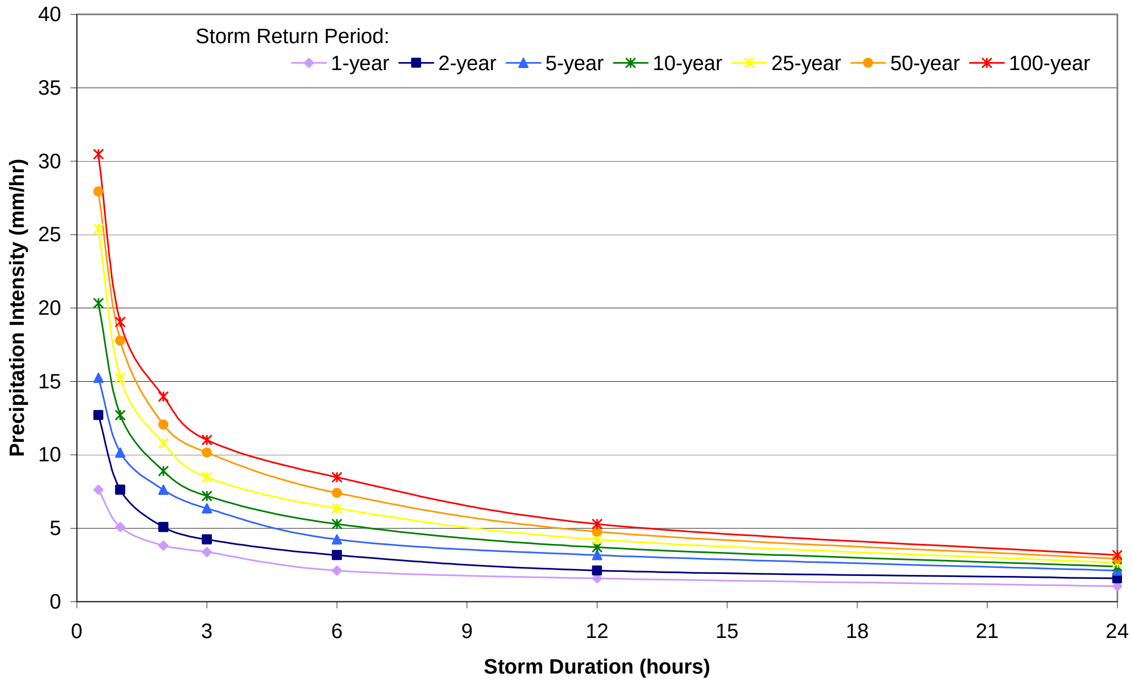


Figure 4.
Big Hurrah IDF Curve

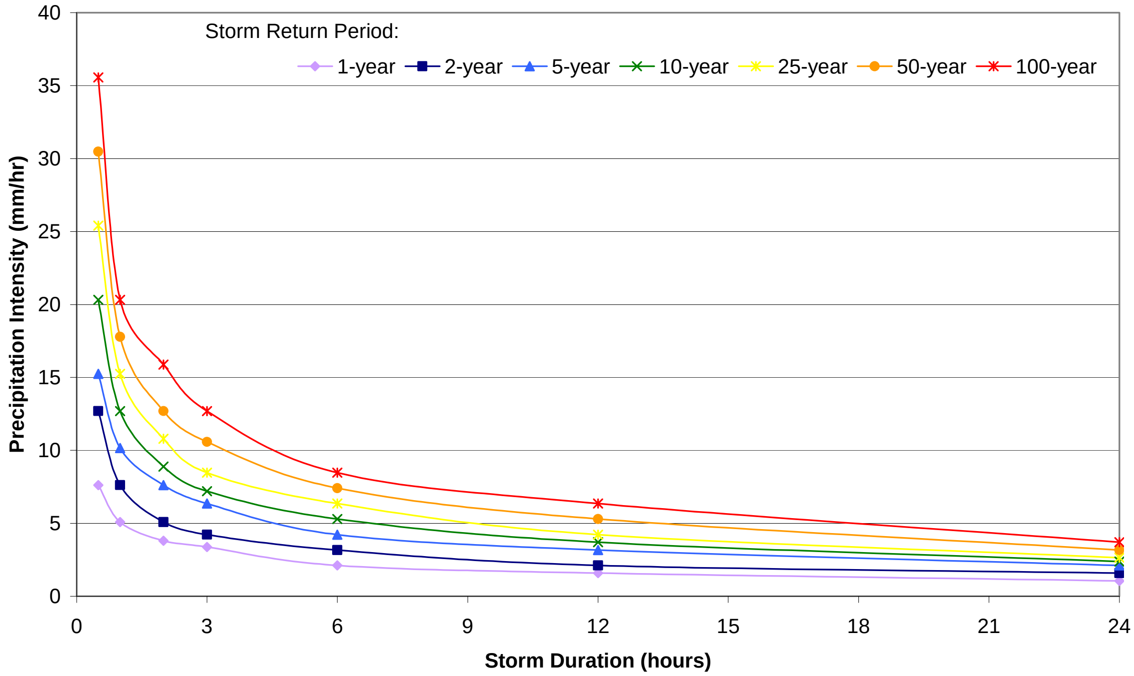


Table 4.
Rainfall Intensity Duration Frequency Values

Return Period (years)	Storm Duration (hours)	Rainfall Intensity (mm/hr) Rock Creek	Rainfall Intensity (mm/hr) Big Hurrah
1	0.5	7.6	7.6
1	1	5.1	5.1
1	2	3.8	3.8
1	3	3.4	3.4
1	6	2.1	2.1
1	12	1.6	1.6
1	24	1.1	1.1
2	0.5	12.7	12.7
2	1	7.6	7.6
2	2	5.1	5.1
2	3	4.2	4.2
2	6	3.2	3.2
2	12	2.1	2.1
2	24	1.6	1.6
5	0.5	15.2	15.2
5	1	10.2	10.2
5	2	7.6	7.6
5	3	6.4	6.4
5	6	4.2	4.2
5	12	3.2	3.2
5	24	2.1	2.1
10	0.5	20.3	20.3
10	1	12.7	12.7
10	2	8.9	8.9
10	3	7.2	7.2
10	6	5.3	5.3
10	12	3.7	3.7
10	24	2.4	2.4
25	0.5	25.4	25.4
25	1	15.2	15.2
25	2	10.8	10.8
25	3	8.5	8.5
25	6	6.4	6.4
25	12	4.2	4.2
25	24	2.6	2.6
50	0.5	27.9	30.5
50	1	17.8	17.8
50	2	12.1	12.7
50	3	10.2	10.6
50	6	7.4	7.4
50	12	4.8	5.3
50	24	2.9	3.2
100	0.5	30.5	35.6
100	1	19.1	20.3
100	2	14.0	15.9
100	3	11.0	12.7
100	6	8.5	8.5
100	12	5.3	6.4
100	24	3.2	3.7

From the IDF data presented in **Table 4**, total precipitation values for the 100-year storms with 24-hour duration periods at the Rock Creek and Big Hurrah sites were determined to be 76.2 mm and 88.9 mm, respectively. Total precipitation values were distributed into 10-minute incremental values using the SCS Type I Storm Distribution. Storm distributions are shown in **Figures 5** and **6**.

Figure 5.
Rock Creek 100-year 24-hour Storm

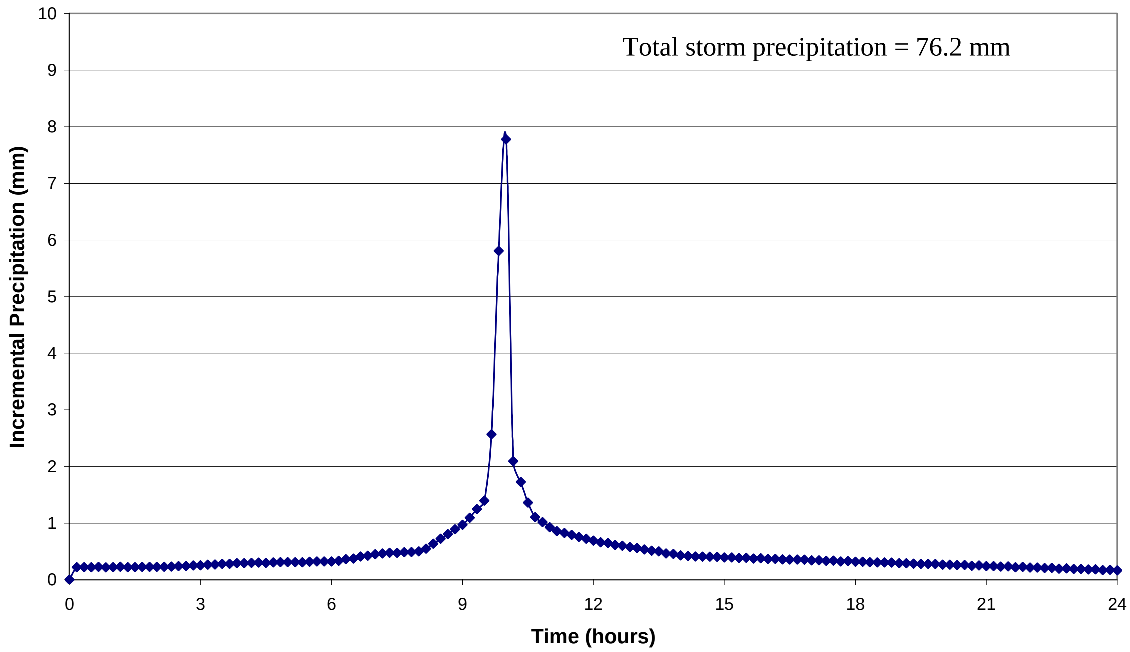
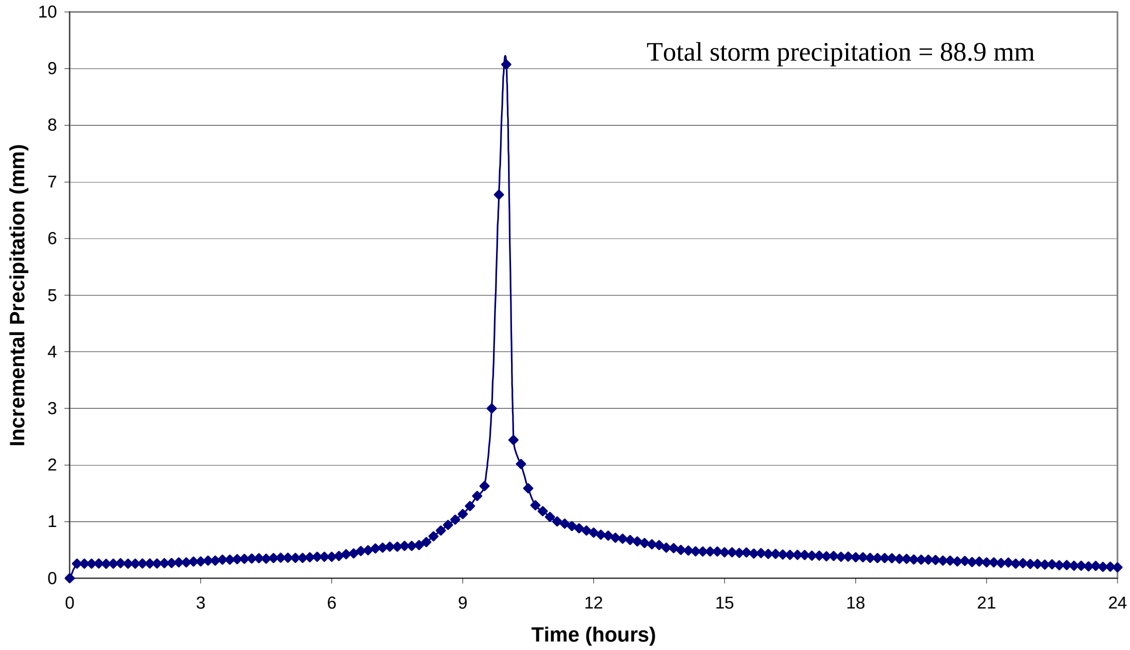


Figure 6.
Big Hurrah 100-year 24-hour Storm



2.1.3 Probable Maximum Precipitation

The probable maximum precipitation (PMP) is defined as a quantity of precipitation that is close to the physical upper limit for a given duration over a particular basin (Chow *et al.*, 1988). The PMP for Nome was calculated using the Hershfield Method and annual maximum precipitation values at Nome obtained from the WRCC. Details of this calculation are presented in **Appendix C**. ERC used the calculated percentages of total precipitation at the Rock Creek and Big Hurrah sites (22% and 37% greater than Nome, respectively) with the PMP value at Nome determine the PMP values at the Rock Creek and Big Hurrah sites. Results are presented in **Table 5**.

Table 5.
Probable Maximum Precipitation

Nome (mm)	Rock Creek (mm)	Big Hurrah (mm)
216.1	263.7	296.1

2.2 Additional Climate Data

Hourly values for wind speed, temperature, relative humidity, barometric pressure, and solar radiation for the year of 2004 were collected at the Rock Creek site by the Hoefler Consulting Group as a part of the Rock Creek Air Monitoring Program. Hourly values were used to compute daily averages for each parameter. Monthly average values were then calculated from daily averages. Results for each parameter are shown in **Table 6**.

Table 6.
Rock Creek Average Monthly Climate Values

Month	Wind Speed (m/s)	Temperature (ºC)	Relative Humidity (%)	Barometric Pressure (mbar)	Solar Radiation (Watts/m^2)
January	4.6	-14.1	68	1013.7	11.2
February	5.5	-12.7	69	998.5	39.9
March	4.4	-11.9	73	1007.2	111.9
April	5.3	-1.5	77	1004.4	149.7
May	3.9	5.1	80	1007.5	161.5
June	3.1	13.2	67	1009.9	236.9
July	2.8	14.6	75	1006.8	214.9
August	3.2	13.9	80	1008.4	124.8
September	3.3	5.0	72	1004.9	106.0
October	4.7	1.7	84	993.0	35.1
November	6.1	-4.7	81	991.7	11.8
December	5.7	-10.2	81	1000.9	2.4

2.3 Evaporation

Evaporation from open water surfaces is calculated with the Penman-Thornthwaite method in this analysis. The Penman-Thornthwaite evaporation method requires data on air temperature, atmospheric pressure, relative humidity and solar radiation. Details of this calculation are presented in **Appendix D**. Hourly values of these parameters were collected at the Rock Creek site by the Hoefler Consulting Group. Hourly values were used to compute a daily average for each parameter, which was used to calculate daily evaporation. Daily evaporation was then summed to a monthly total. It was assumed that no evaporation occurred on days where the average temperature was below freezing.

Comparable data necessary for evaporation calculations have not been collected at the Big Hurrah site. Therefore, evaporation was quantified at the Rock Creek site only and will be used for both locations. Total monthly evaporation at the Rock Creek site is shown in **Table 7**.

Table 7.
Rock Creek Evaporation

Month	Total Evaporation (mm)
January	0.0
February	3.1
March	0.0
April	52.1
May	98.0
June	170.2
July	157.9
August	93.2
September	58.4
October	21.1
November	0.3
December	0.0

It should be noted that February and November each had only one day with average temperatures above freezing. As it was assumed that no evaporation occurred on days where the average temperature was below freezing, water loss for these months is likely to be more accurately represented by snow sublimation as presented in Section 2.5. It will be possible to quantify evaporation during the months of February and November with greater accuracy as more data become available.

2.4 Evapotranspiration

Evapotranspiration is the combination of evaporation from the soil surface and transpiration from vegetation (Chow *et al.*, 1988). Calculations of evapotranspiration are made using evaporation calculation methods with adjustments to account for the condition of the vegetation and soil.

In this analysis, the combination Penman-Thornthwaite method for evaporation over open water was applied, with an adjustment to account for land condition based on wind speed (Chow *et al.*, 1988). Details of this calculation are presented in **Appendix E**. Hourly data collected by the Hoefler Consulting Group were used to calculate daily evapotranspiration values as described in Section 2.3. Daily evapotranspiration was summed to a monthly total. It was assumed that no evapotranspiration occurred on days where the average temperature was below freezing.

Comparable data necessary for evapotranspiration calculations have not been collected at the Big Hurrah site. Therefore, evapotranspiration was quantified at the Rock Creek site only and will be used for both locations. Total monthly evapotranspiration at the Rock Creek site is shown in **Table 8**.

Table 8.
Rock Creek Evapotranspiration

Month	Total Evapotranspiration (mm)
January	0.0
February	7.2
March	0.0
April	70.0
May	121.7
June	215.3
July	191.3
August	118.4
September	83.5
October	34.6
November	0.8
December	0.0

It should be noted that February and November each had only one day with average temperatures above freezing. As it was assumed that no evapotranspiration occurred on days where the average temperature was below freezing, water loss for these months is likely to be more accurately represented by snow sublimation as presented in Section 2.5. It will be possible to quantify evapotranspiration during the months of February and November with greater accuracy as more data become available.

2.5 Snow Sublimation

Sublimation is the direct conversion of solid snow or ice to water vapor. Calculations of daily surface (not intercepted or blowing) snow sublimation are based on wind speed, air vapor pressure, and saturated vapor pressure over ice (Gelfan *et al.*, 2004). Details of this calculation are presented in **Appendix F**.

In this analysis, total monthly sublimation was calculated using hourly data collected at the Rock Creek site by the Hoefler Consulting Group. Hourly values were used to compute a daily average for each required parameter, which were then used to calculate daily sublimation. Daily sublimation was summed to a monthly total. Sublimation at the Rock Creek site was calculated for the months of November, December, January, February, and March, where below-freezing temperatures were recorded for more than half of all days. Sublimation was not calculated at the Big Hurrah site, as necessary climatological data have not been collected. Calculated values for Rock Creek will be used for both sites.

Total sublimation values at the Rock Creek site represent a depth of snow converted to water vapor. In order to convert snow depth to the corresponding depth of water, the snow-water equivalent is necessary. Average monthly snow-water equivalent values were determined for the months of November, December, January, February, and March at the Nome Municipal Airport. Snow water equivalents were calculated from average total precipitation, which includes the liquid water equivalent of snowfall and average total snow fall data. These data are available through the Western Regional Climate Center for the period between 1949 and 2005, and were assumed applicable to the Rock Creek site snowpack, as no snowfall data are available at that site. Snow-water equivalent values for the months of November, December, January, February, and March at the Nome Municipal Airport are presented in **Appendix F**.

Total monthly sublimation and water-equivalent results are shown in **Table 9.** It should be noted that equivalent sublimated water results based on calculated snow-water equivalent values represent minimum water loss, as they do not take snow compaction and settling in to account. Calculated snow-water equivalent values range between 9 and 10 percent water content. However, as snow settles, it may reach up to a 30-35% water content before melting (Rick McClure, Anchorage Natural Resources Conservation Service, Personal Communication 09/01/05). Therefore, equivalent water results determined from calculated snow-water equivalent values are listed as “minimum” in **Table 9**. Equivalent water values were also calculated using 35% water content, and are listed as “maximum” in **Table 9**.

Table 9.
Rock Creek Sublimation

Month	Total Sublimation (mm)	Equivalent Water (mm) Minimum	Equivalent Water (mm) Maximum
November	113.0	11.2	39.6
December	60.6	5.3	21.2
January	99.4	9.2	34.8
February	136.6	11.8	47.8
March	58.7	5.0	20.5

Although no snow sublimation data are available at the Nome Airport for comparison, these results were compared to published snow sublimation research in the Imnavait Creek watershed. This watershed is located on the northern slope of Alaska at the foothills of the Brooks Range. Seasonal totals of equivalent water minimum values presented in **Table 9** are consistent with published data for the Imnavait Creek watershed (Yang *et al.*, 2000). Further, monthly totals of equivalent water minimum values presented in **Table 9** fall within the range of published results for research locations in the western continental US (Fassnacht, 2004).

2.6 Snow Melt

The WRCC maintains a record of average daily snow depth at the Nome Airport for the period between 1949 and March 31, 2005. Recorded results are shown graphically in **Appendix G**, and suggest that nearly all snow melts during the months of April and May. For the purpose of water balance analysis, ERC recommends assuming that half of the snow melts in April, and the remainder in May. This assumption is supported by the graph presented in **Appendix G**.

Analysis of the snow melt rate suggests that rainfall runoff associated with the 100-year 24-hour storm acts as the controlling criteria for facilities design at the proposed Rock Creek and Big Hurrah sites, rather than snow melt. The water produced by snow melt, using a maximum water equivalent of settled snow and the snow melt rate indicated in **Appendix G**, is delivered with an intensity two orders of magnitude less than the precipitation intensity of 100-year 24-hour storm. Further, April and May receive approximately one quarter to one third of the precipitation that falls during the wettest months of July, August, and September. Rainfall would therefore not significantly contribute to the intensity of the total water delivered by snow melt.

3.0 References

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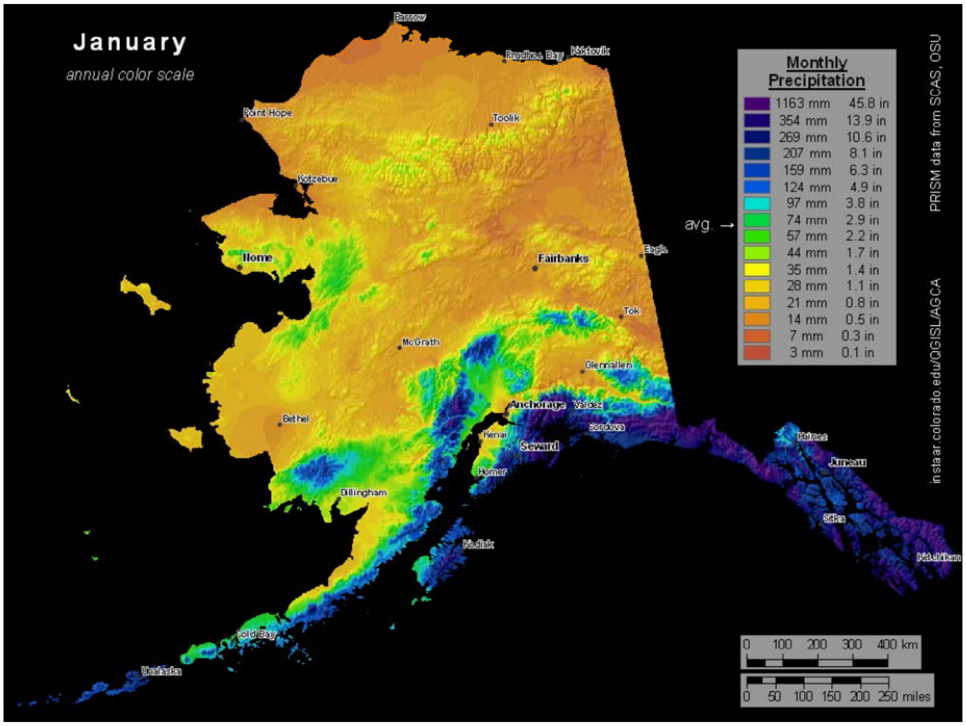
APPENDIX A:

Average Monthly Precipitation Maps


January
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/QGISL/AGCA
Point Hope
Toolik
Kotzebue
Nome
Fairbanks
Tok
McGrath
Glennallen
Anchorage
Valdez
Bethel
Kenai
Seward
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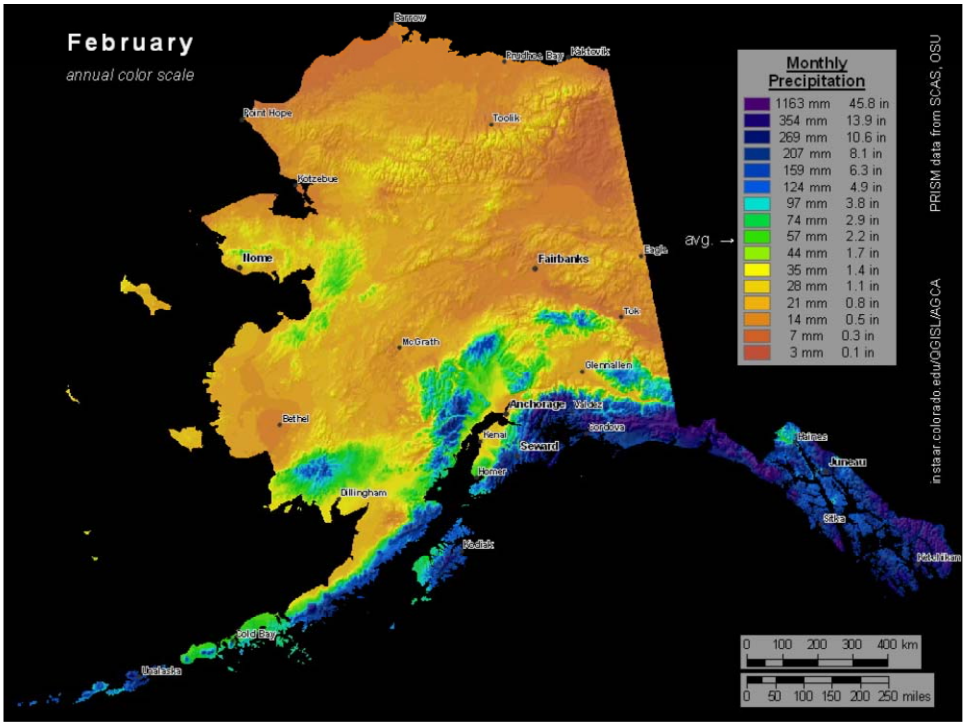
February
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
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44 mm 1.7 in
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28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/QGISL/AGCA
Point Hope
Toolik
Kotzebue
Nome
Fairbanks
Tok
McGrath
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Seward
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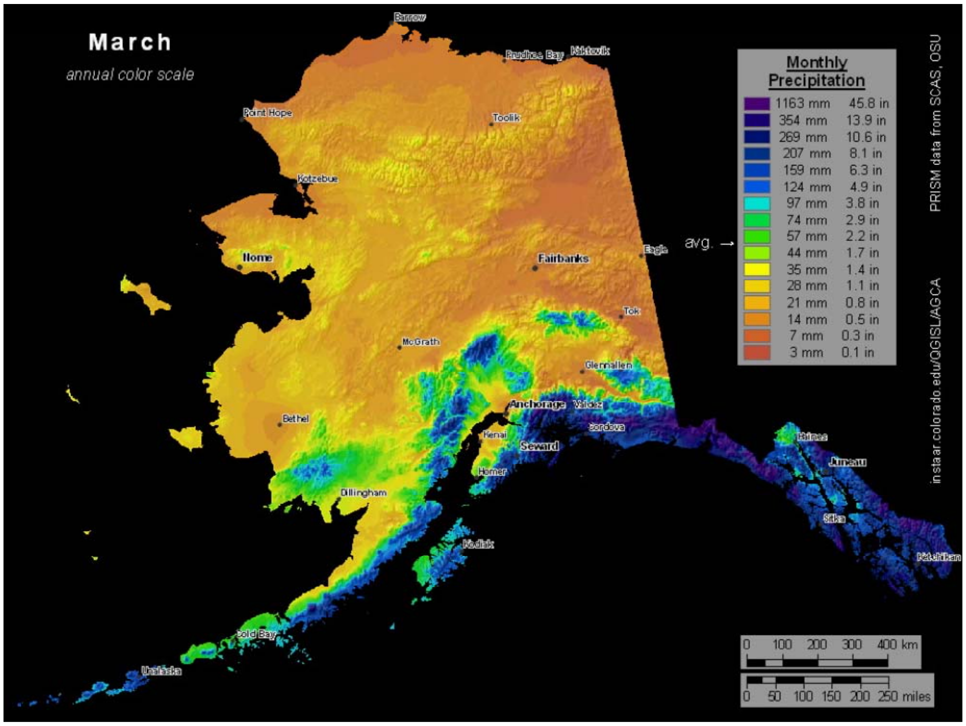
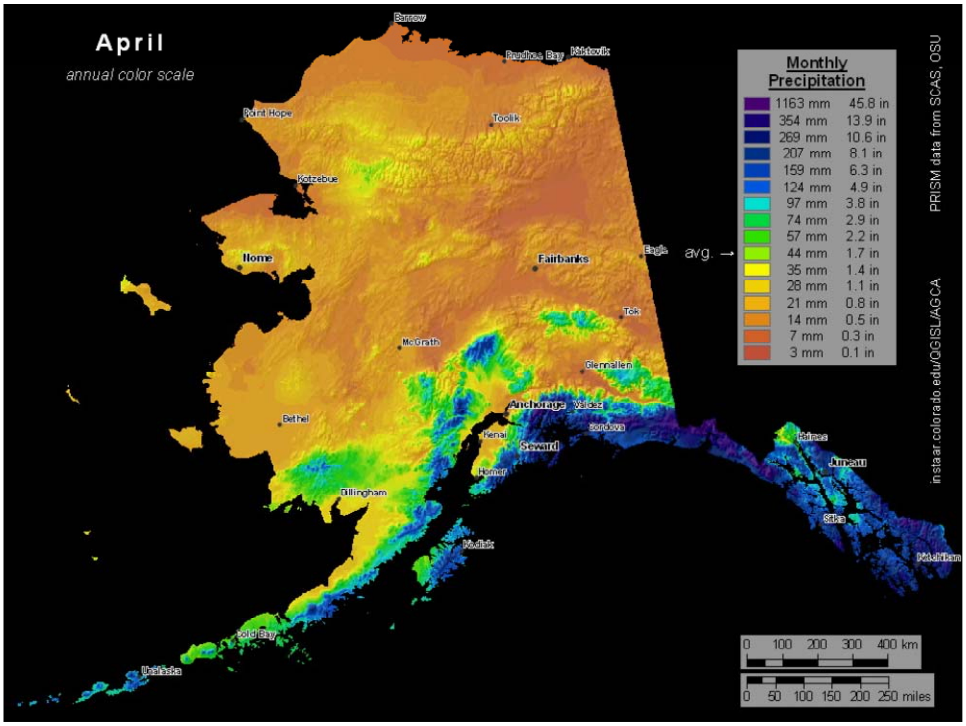
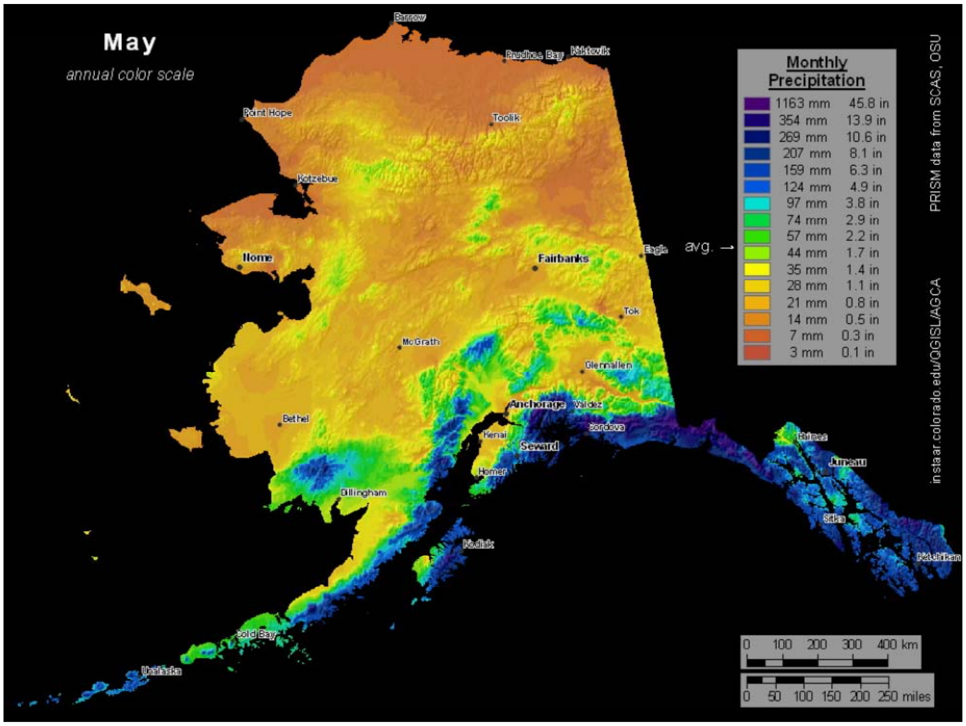
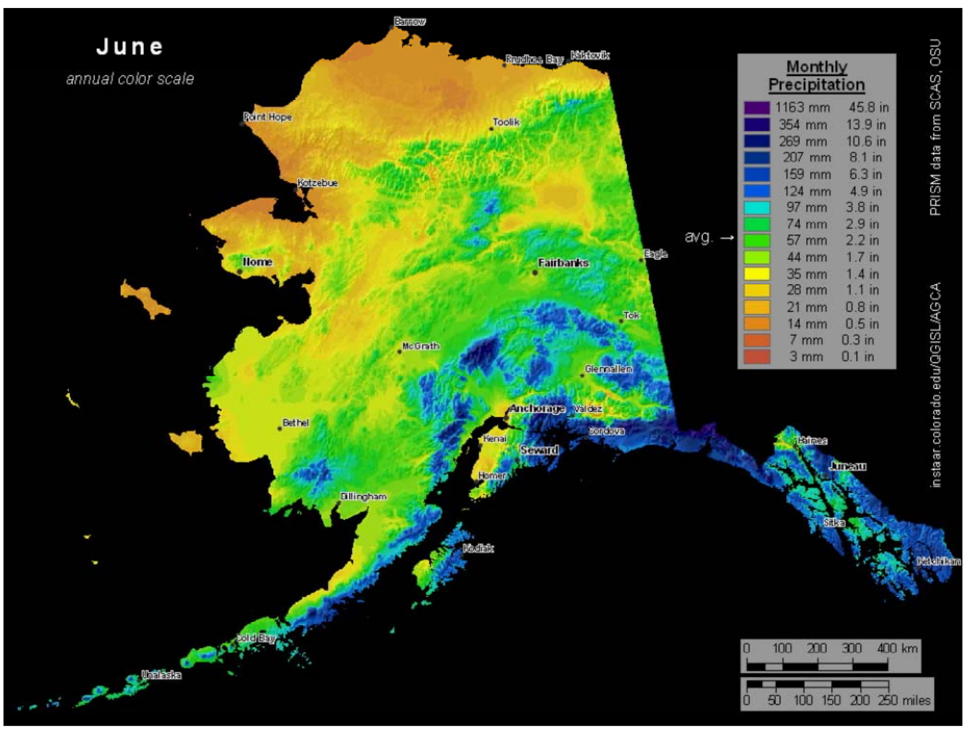
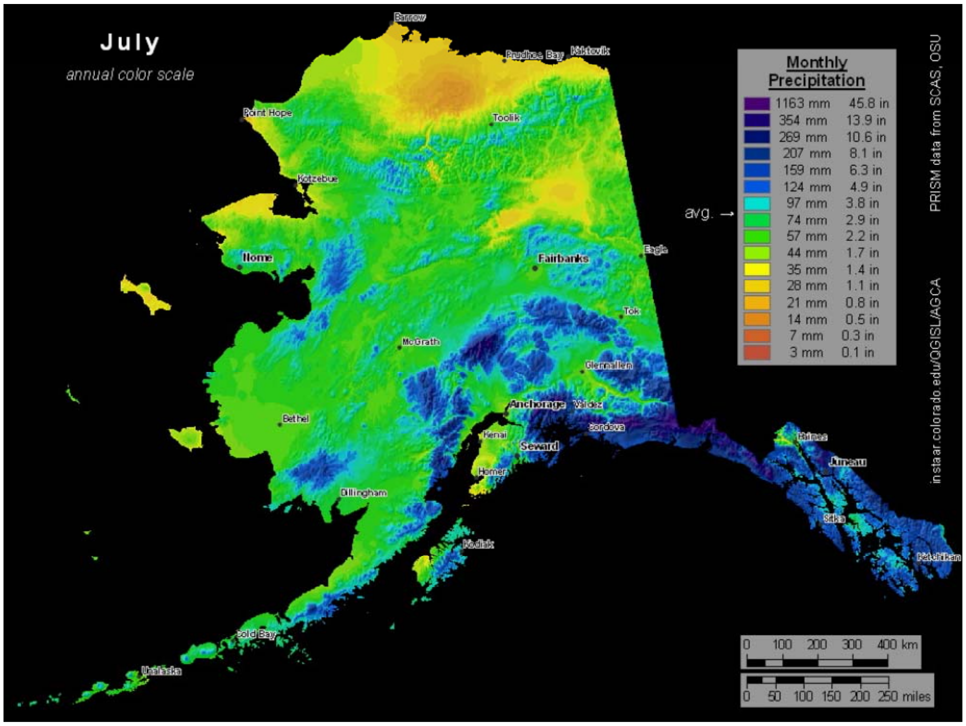
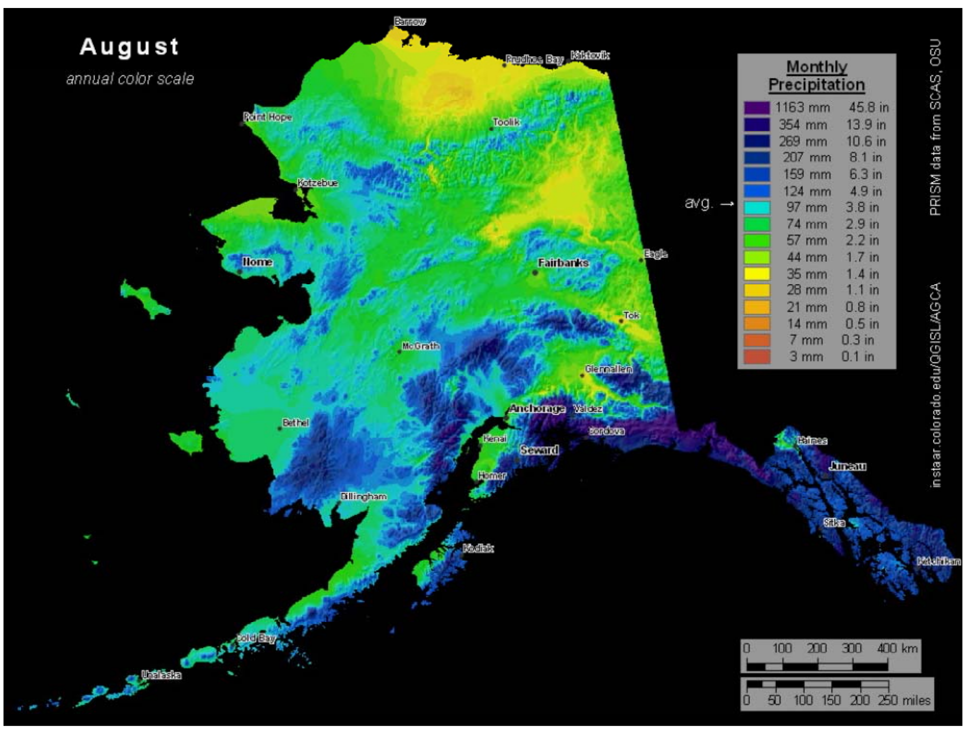

March
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/QGISL/AGCA
Fairbanks
Anchorage
Seward
0 100 200 300 400 km
0 50 100 150 200 250 miles

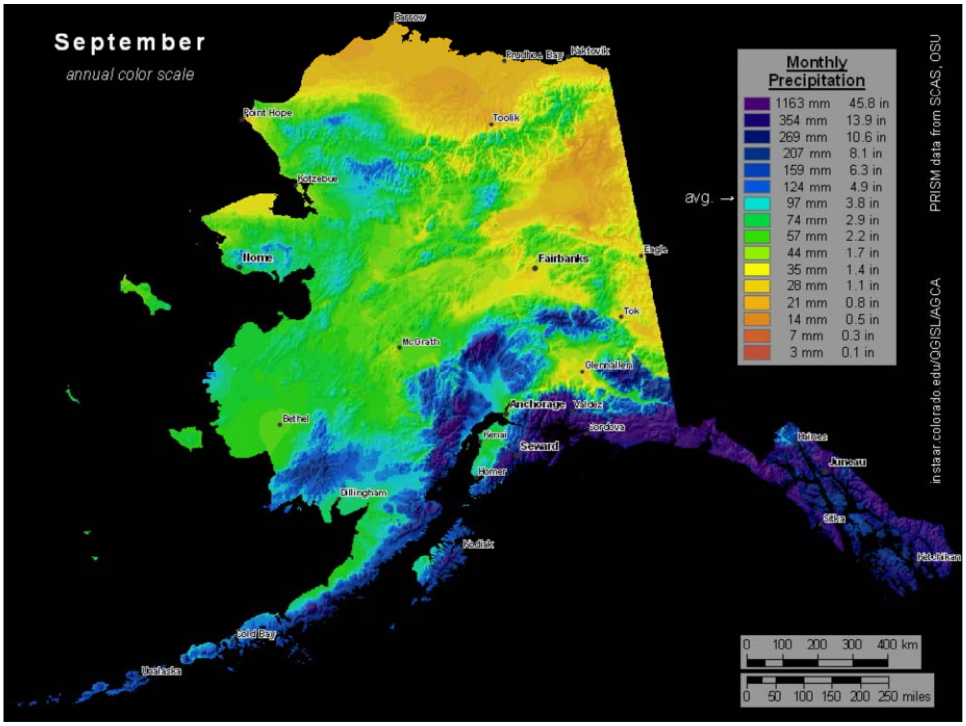

April
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/QGISL/AGCA
Fairbanks
Anchorage
Seward
0 100 200 300 400 km
0 50 100 150 200 250 miles

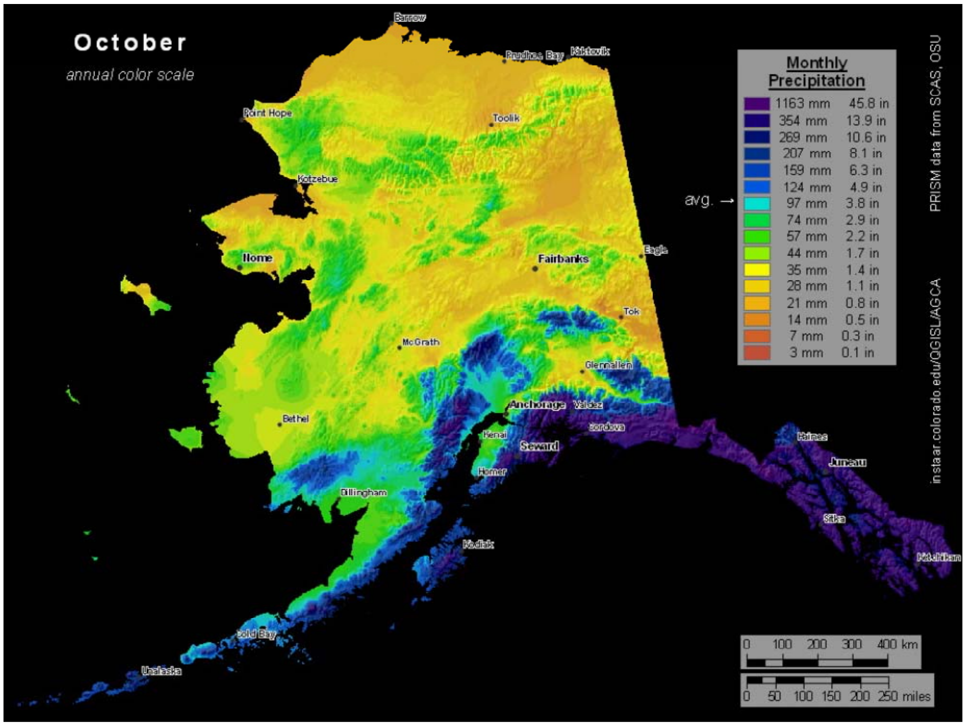

May
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg.
PRISM data from SCAS, OSU
instaar.colorado.edu/QGISL/AGCA
Point Hope
Toolik
Kotzebue
Nome
Fairbanks
Tok
McGrath
Glennallen
Anchorage
Valdez
Bethel
Seward
Homer
Dillingham
Juneau
Cold Bay
0 100 200 300 400 km
0 50 100 150 200 250 miles

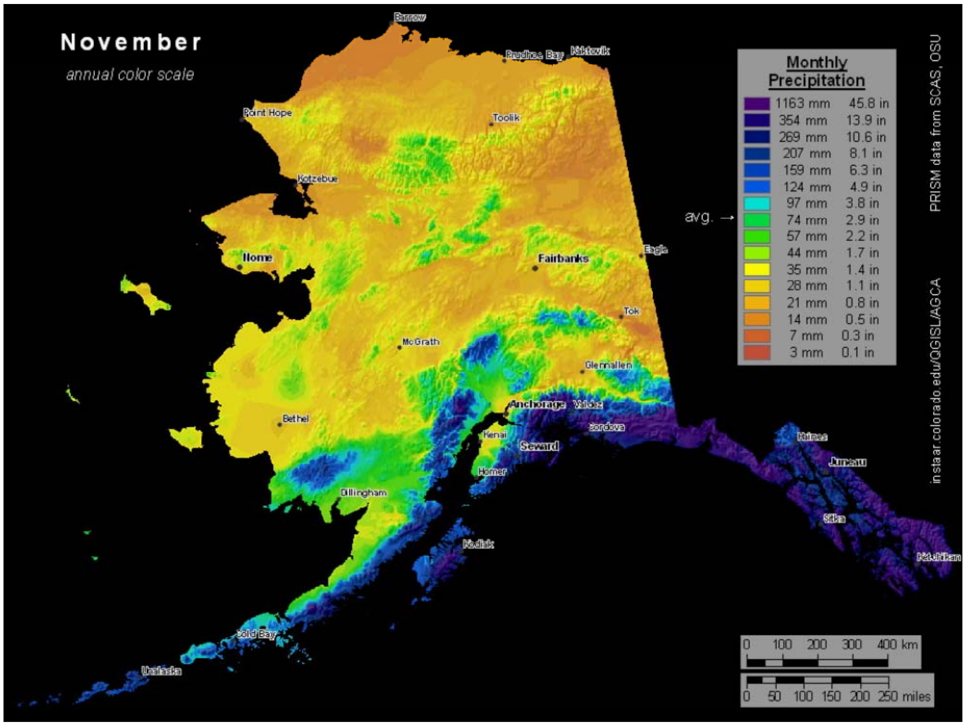

June
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg.
PRISM data from SCAS, OSU
instaar.colorado.edu/QGISL/AGCA
Point Hope
Toolik
Kotzebue
Nome
Fairbanks
Tok
McGrath
Glennallen
Anchorage
Valdez
Bethel
Seward
Homer
Dillingham
Juneau
Cold Bay
0 100 200 300 400 km
0 50 100 150 200 250 miles

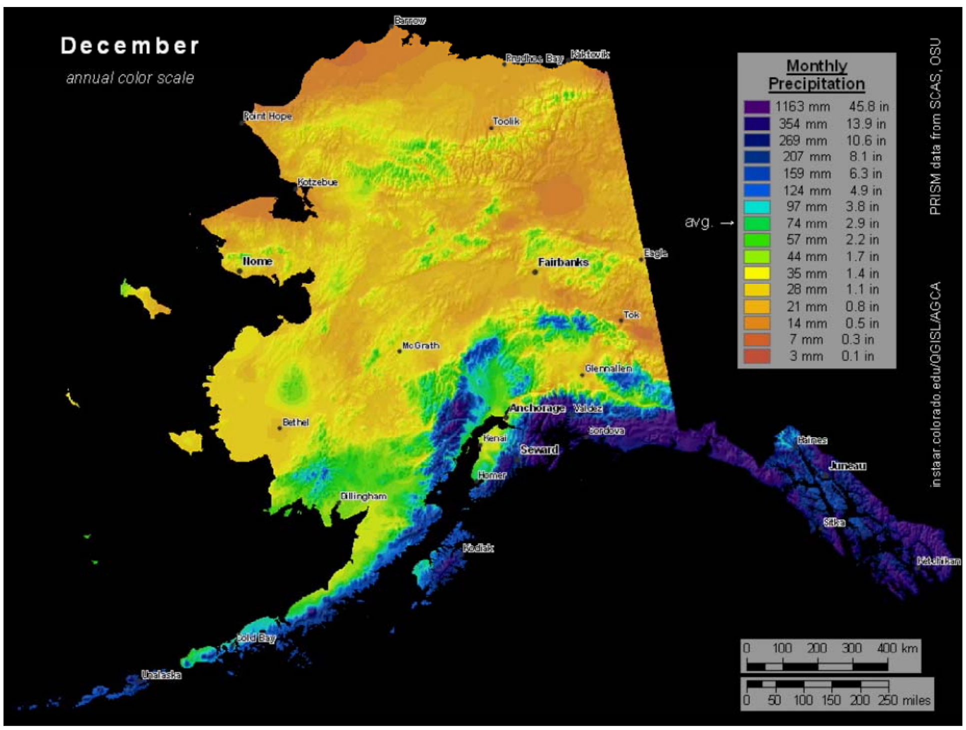

July
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/QGISL/AGCA
Point Hope
Kotzebue
Toolik
Nome
Fairbanks
Eagle
Tok
McGrath
Glennallen
Anchorage
Bethel
Kenai
Seward
Homer
Dillingham
Kodiak
Juneau
Sitka
Cold Bay
0 100 200 300 400 km
0 50 100 150 200 250 miles


August
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/QGISL/AGCA
Point Hope
Kotzebue
Toolik
Nome
Fairbanks
Eagle
Tok
McGrath
Glennallen
Anchorage
Bethel
Kenai
Seward
Homer
Dillingham
Kodiak
Juneau
Sitka
Cold Bay
0 100 200 300 400 km
0 50 100 150 200 250 miles


September
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/OGISL/AGCA
Barrow
Point Hope
Toolik
Kotzebue
Nome
Fairbanks
Eagle
Tok
McGrath
Glennallen
Anchorage
Valdez
Cordova
Bethel
Kenai
Seward
Homer
Dillingham
Haines
Juneau
Sitka
Kodiak
Cold Bay
0 100 200 300 400 km
0 50 100 150 200 250 miles


October
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/OGISL/AGCA
Barrow
Point Hope
Toolik
Kotzebue
Nome
Fairbanks
Eagle
Tok
McGrath
Glennallen
Anchorage
Valdez
Cordova
Bethel
Kenai
Seward
Homer
Dillingham
Haines
Juneau
Sitka
Kodiak
Cold Bay
0 100 200 300 400 km
0 50 100 150 200 250 miles


November
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/OGISL/AGCA
Point Hope
Toolik
Kotzebue
Nome
Fairbanks
Eagle
Tok
McGrath
Glennallen
Anchorage
Bethel
Kenai
Seward
Homer
Dillingham
Kodiak
Cold Bay
0 100 200 300 400 km
0 50 100 150 200 250 miles


December
annual color scale
Monthly Precipitation
1163 mm 45.8 in
354 mm 13.9 in
269 mm 10.6 in
207 mm 8.1 in
159 mm 6.3 in
124 mm 4.9 in
97 mm 3.8 in
74 mm 2.9 in
57 mm 2.2 in
44 mm 1.7 in
35 mm 1.4 in
28 mm 1.1 in
21 mm 0.8 in
14 mm 0.5 in
7 mm 0.3 in
3 mm 0.1 in
avg. →
PRISM data from SCAS, OSU
instaar.colorado.edu/OGISL/AGCA
Point Hope
Toolik
Kotzebue
Nome
Fairbanks
Eagle
Tok
McGrath
Glennallen
Anchorage
Bethel
Kenai
Seward
Homer
Dillingham
Kodiak
Cold Bay
0 100 200 300 400 km
0 50 100 150 200 250 miles

APPENDIX B:

Isohyetal Maps

1y 30 min

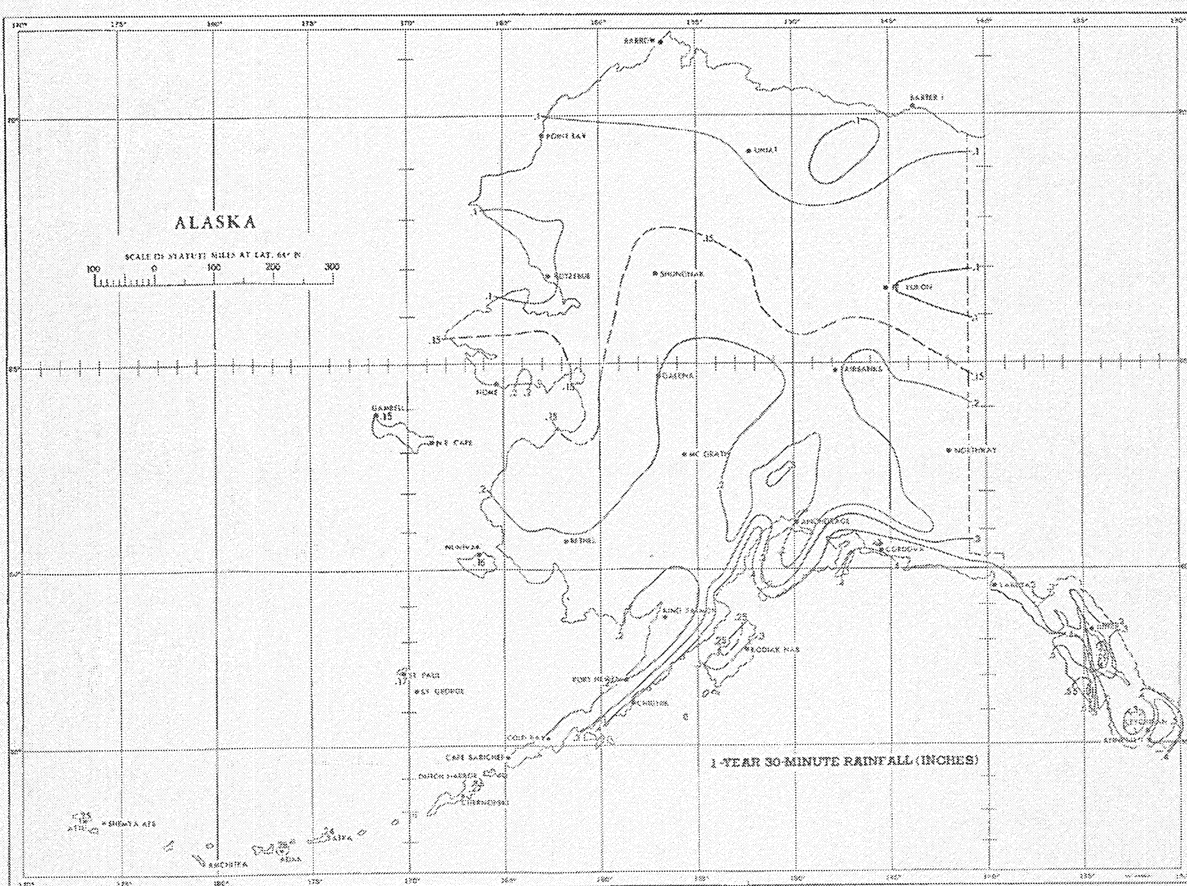
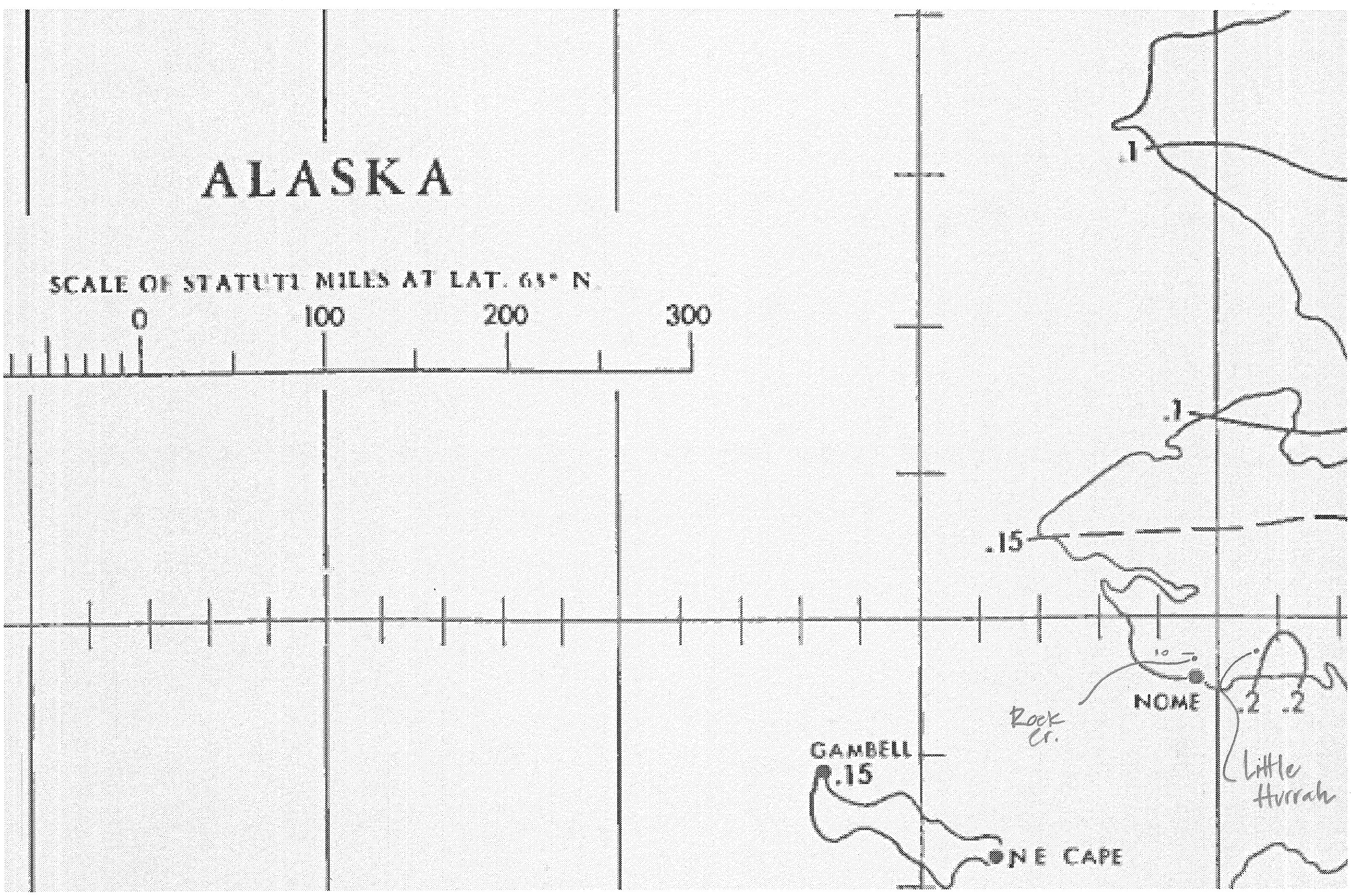


FIGURE 3-11.—1-yr. 30-min. rainfall (in.).

1 year
30 min


ALASKA
SCALE OF STATUTE MILES AT LAT. 65° N
0
100
200
300
.1
.1
.15
NOME
.2
.2
Rock Cr.
Little Hurrah
GAMBELL
.15
NE CAPE

2yr - 30 min

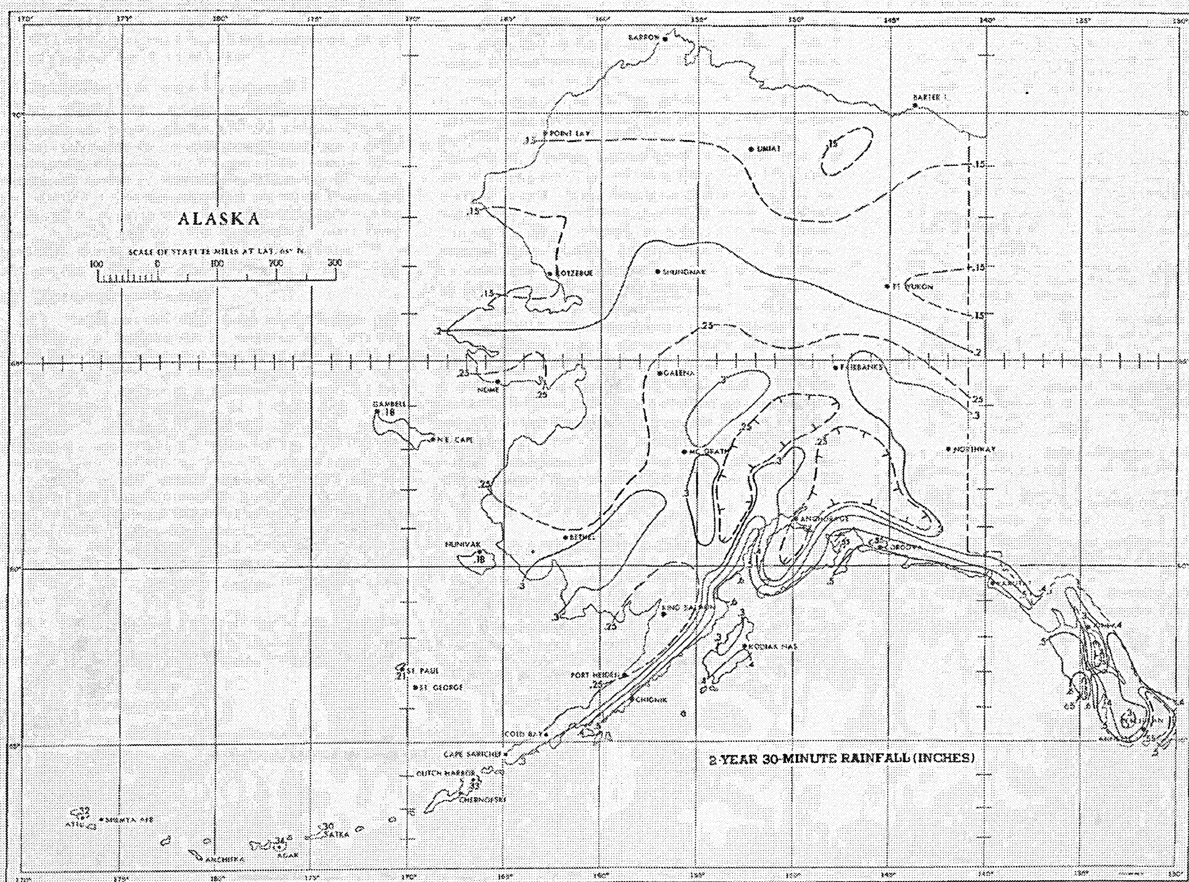


FIGURE 3-12.—2-yr. 30-min. rainfall (in.).

5 yr
30 min

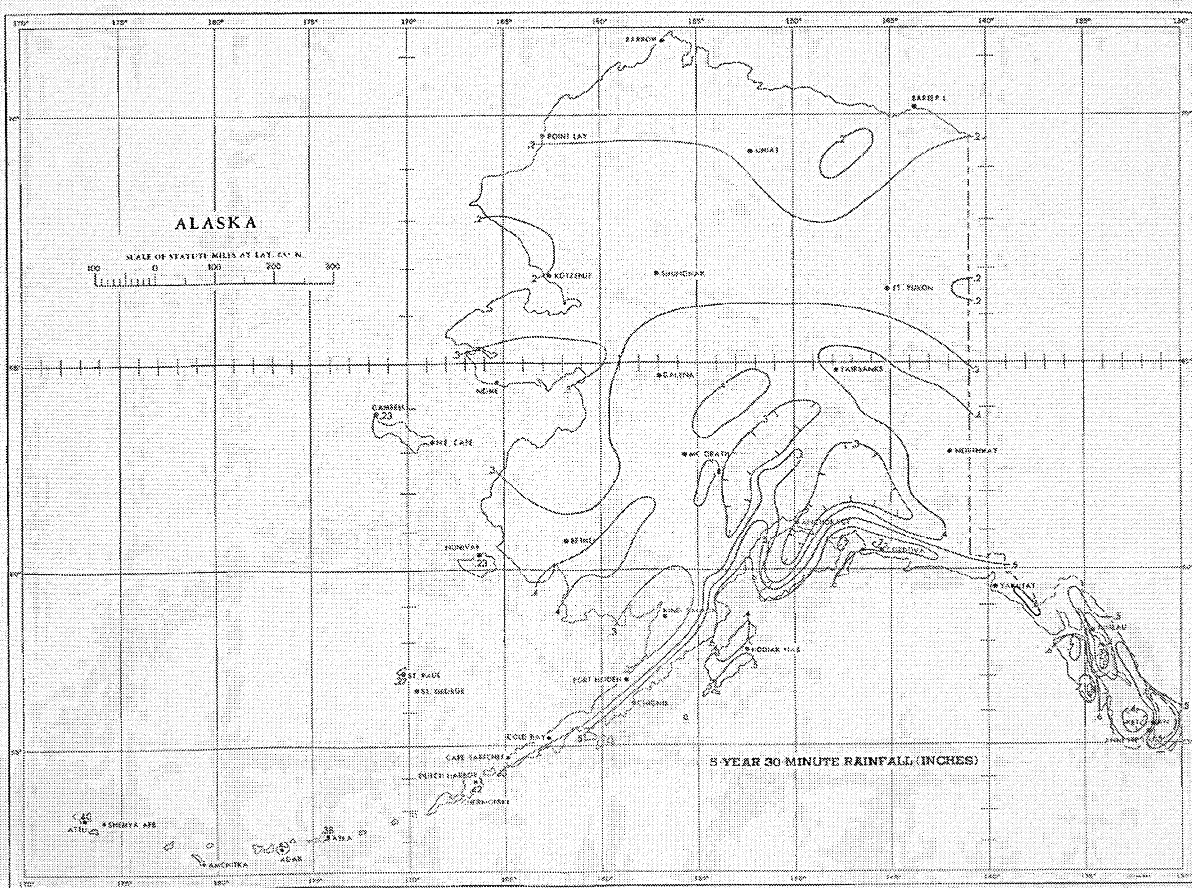


FIGURE 3-13.—5-yr. 30-min. rainfall (in.).

10 yr 30 min

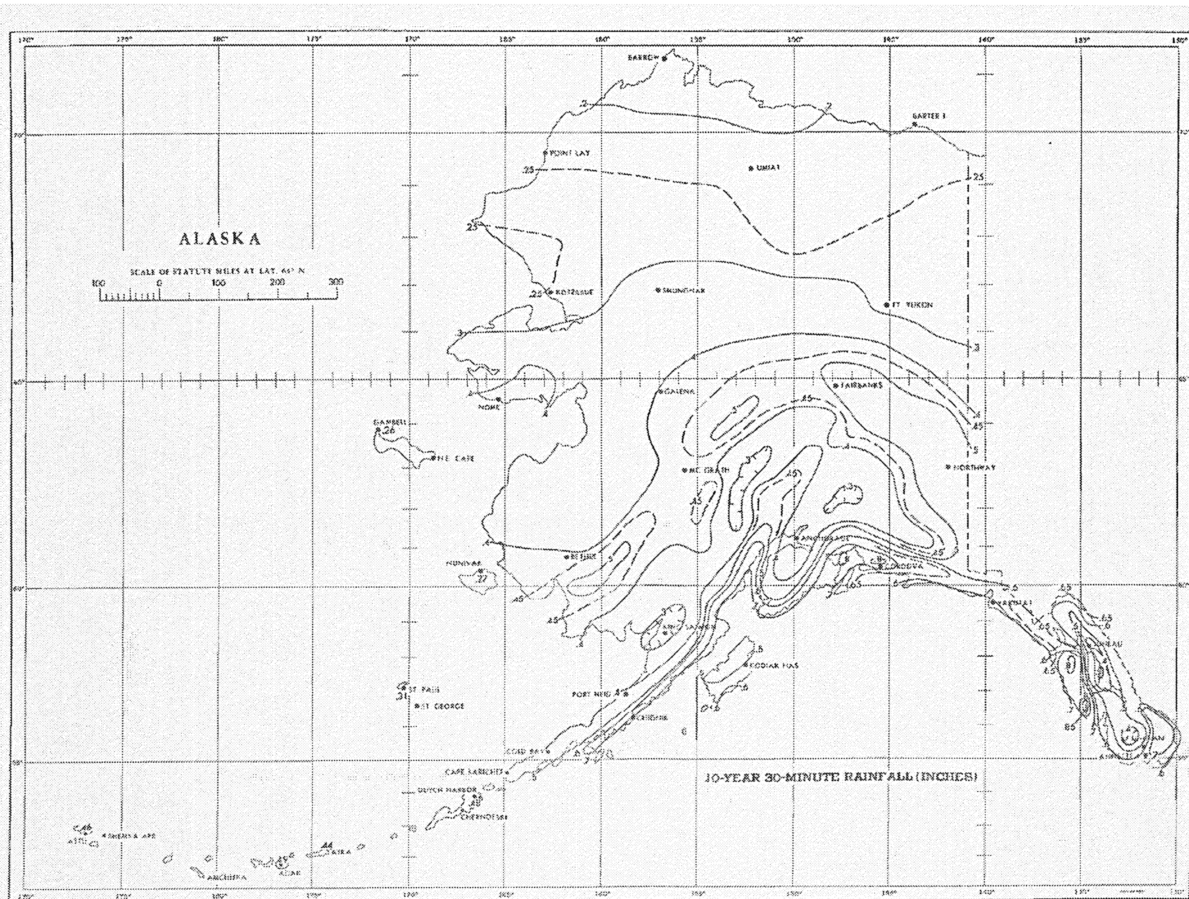


FIGURE 3-14.—10-yr. 30-min. rainfall (in.).

25 yr 30 min

Rock .5
Hurr .5

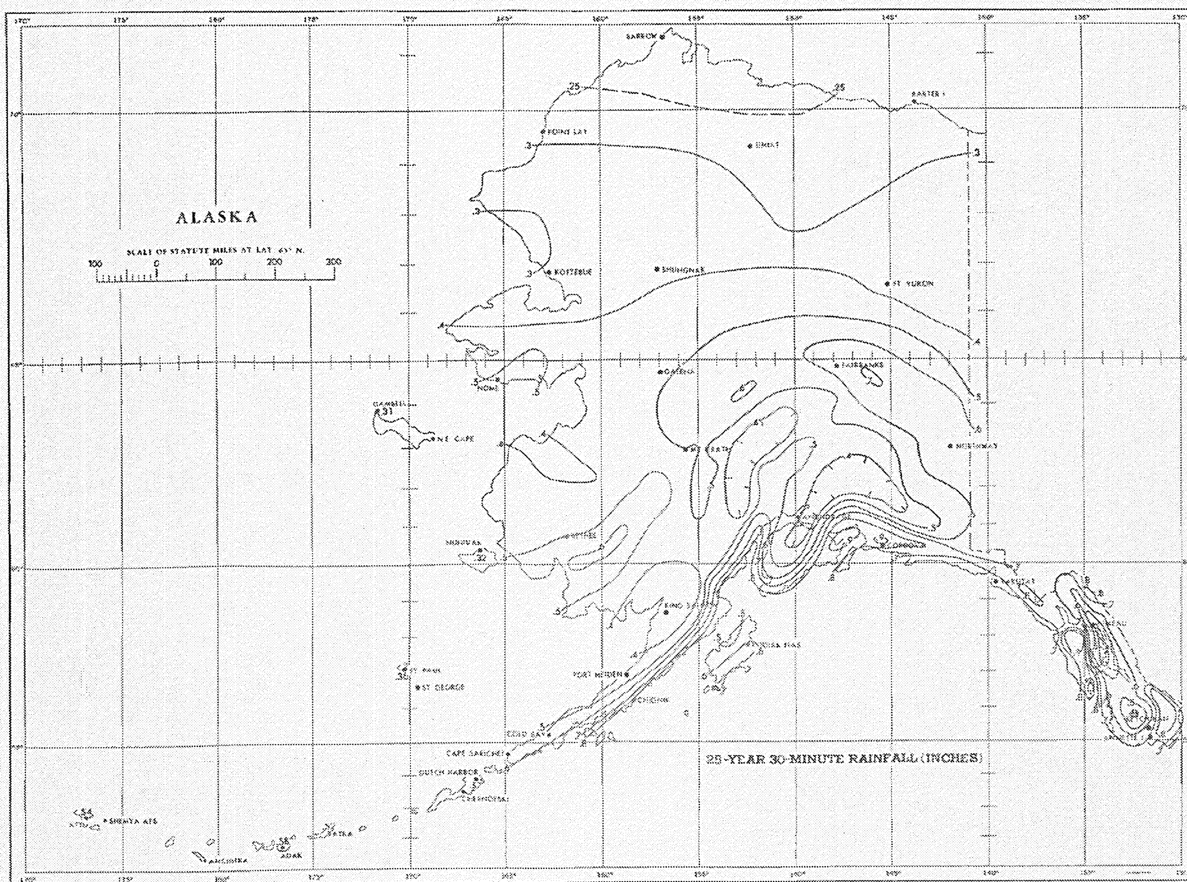


FIGURE 3-15.—25-yr. 30-min. rainfall (in.).

50 yr 30 min

.5 Rock
.6 Hurrah

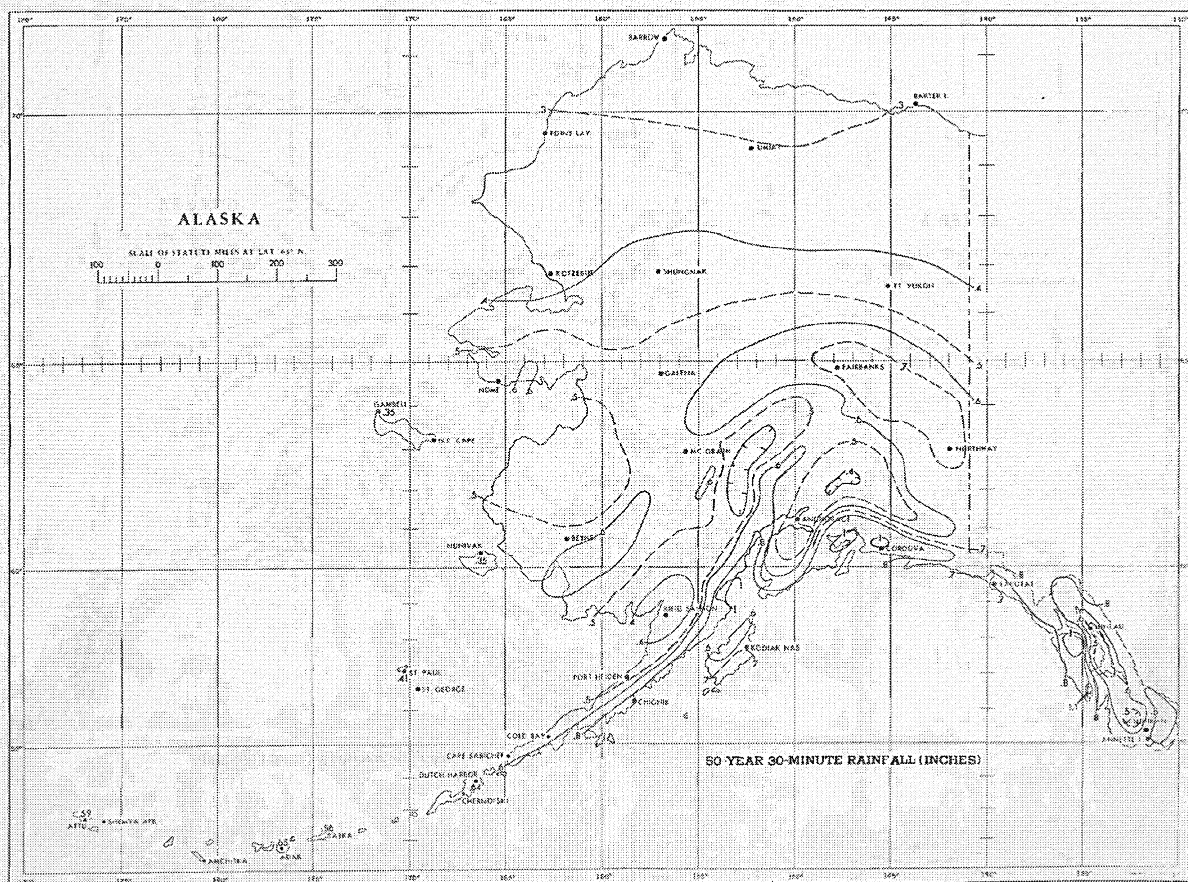


FIGURE 3-16.—50-yr. 30-min. rainfall (in.).

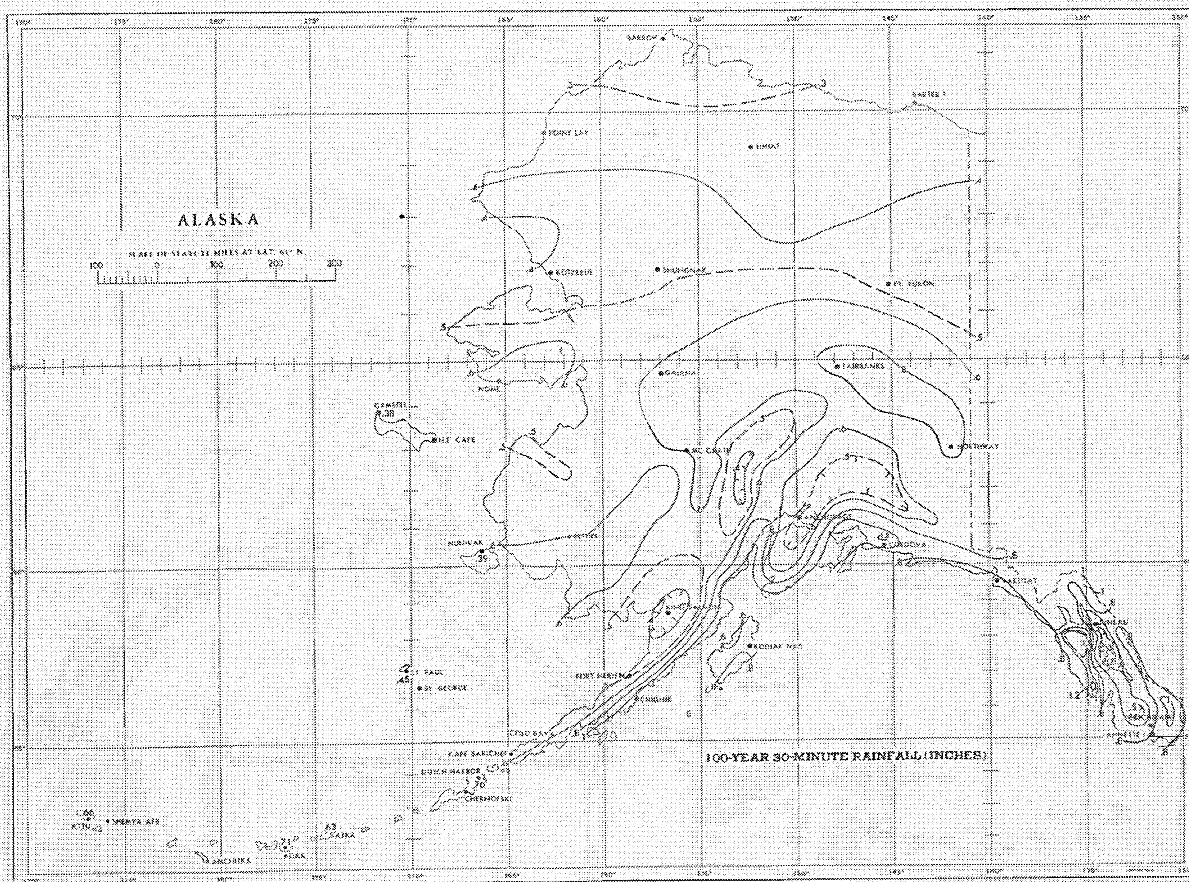


FIGURE 3-17.—100-yr. 30-min. rainfall (in.).

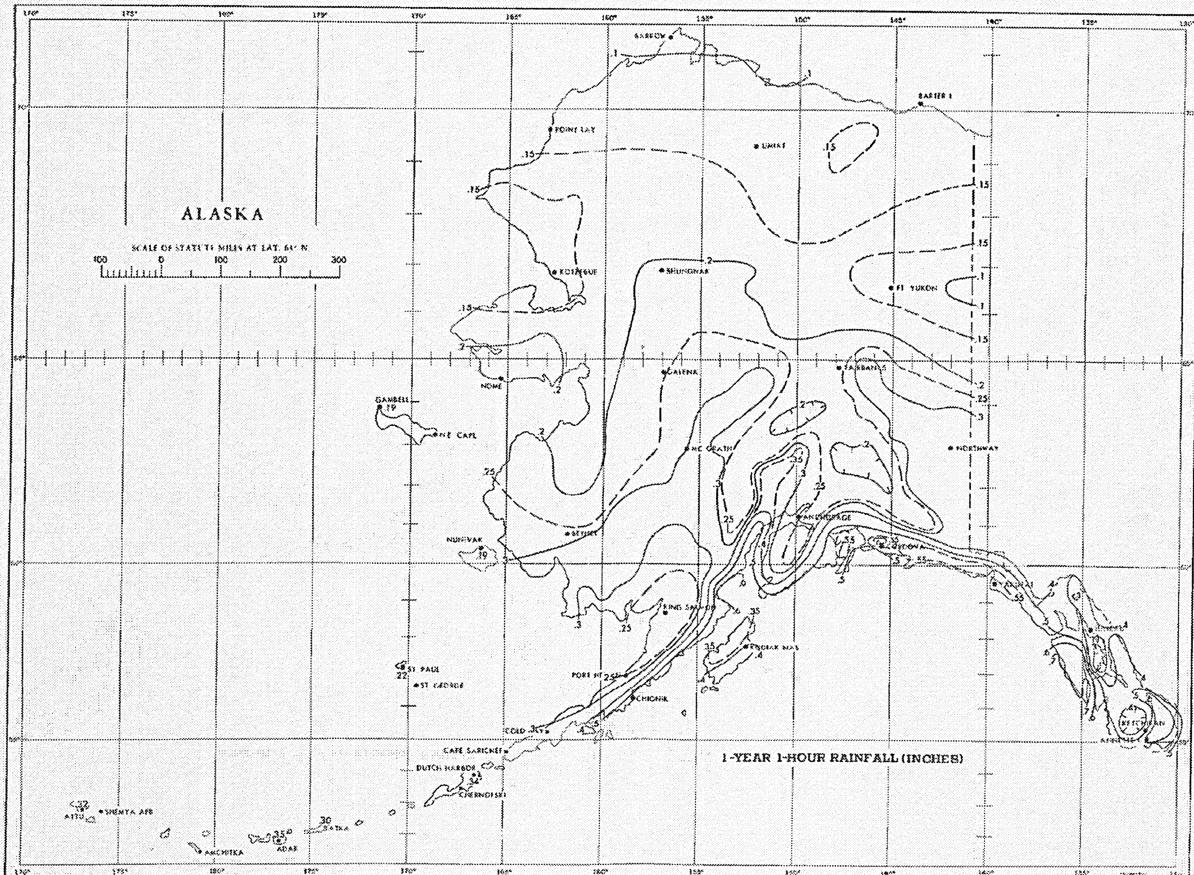


FIGURE 3-18.—1-yr. 1-hr. rainfall (in.).

2yr 1h

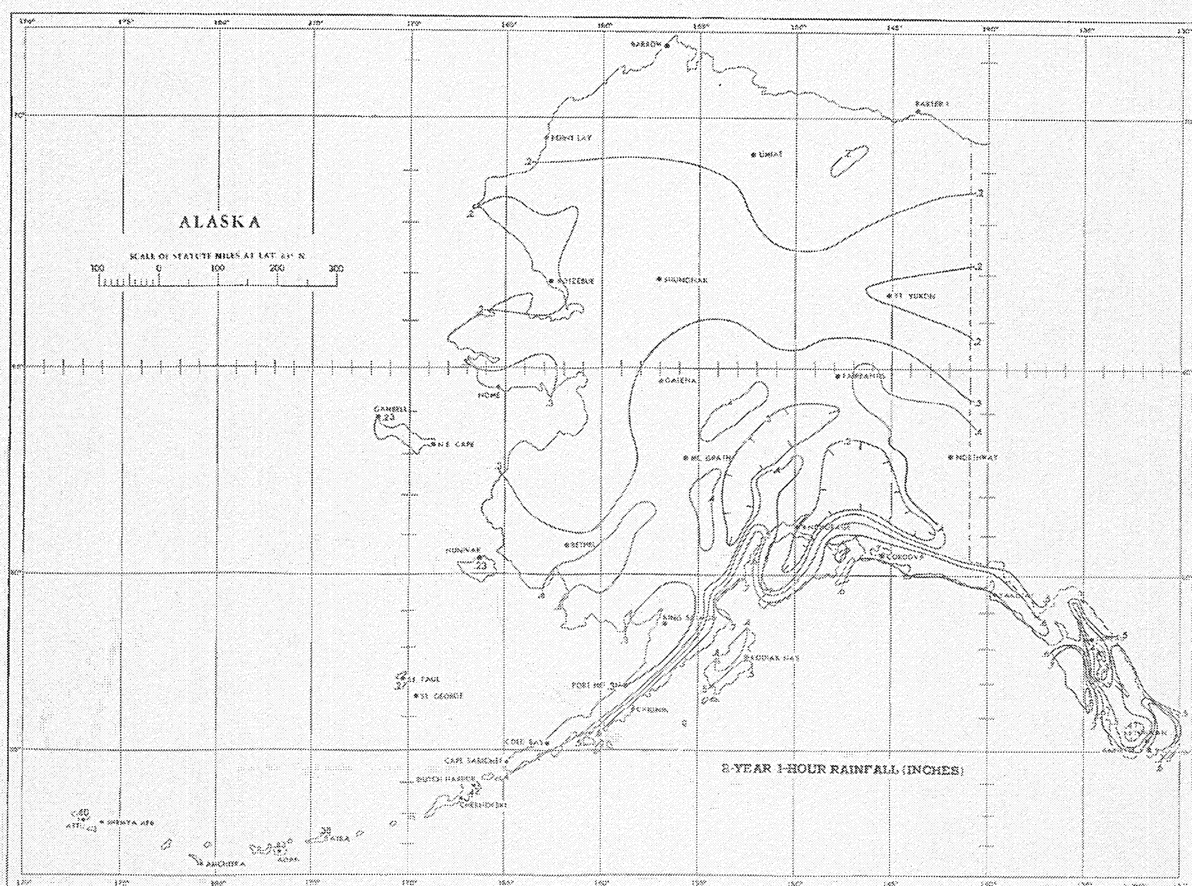


FIGURE 3-19.—2-yr. 1-hr. rainfall (in.).

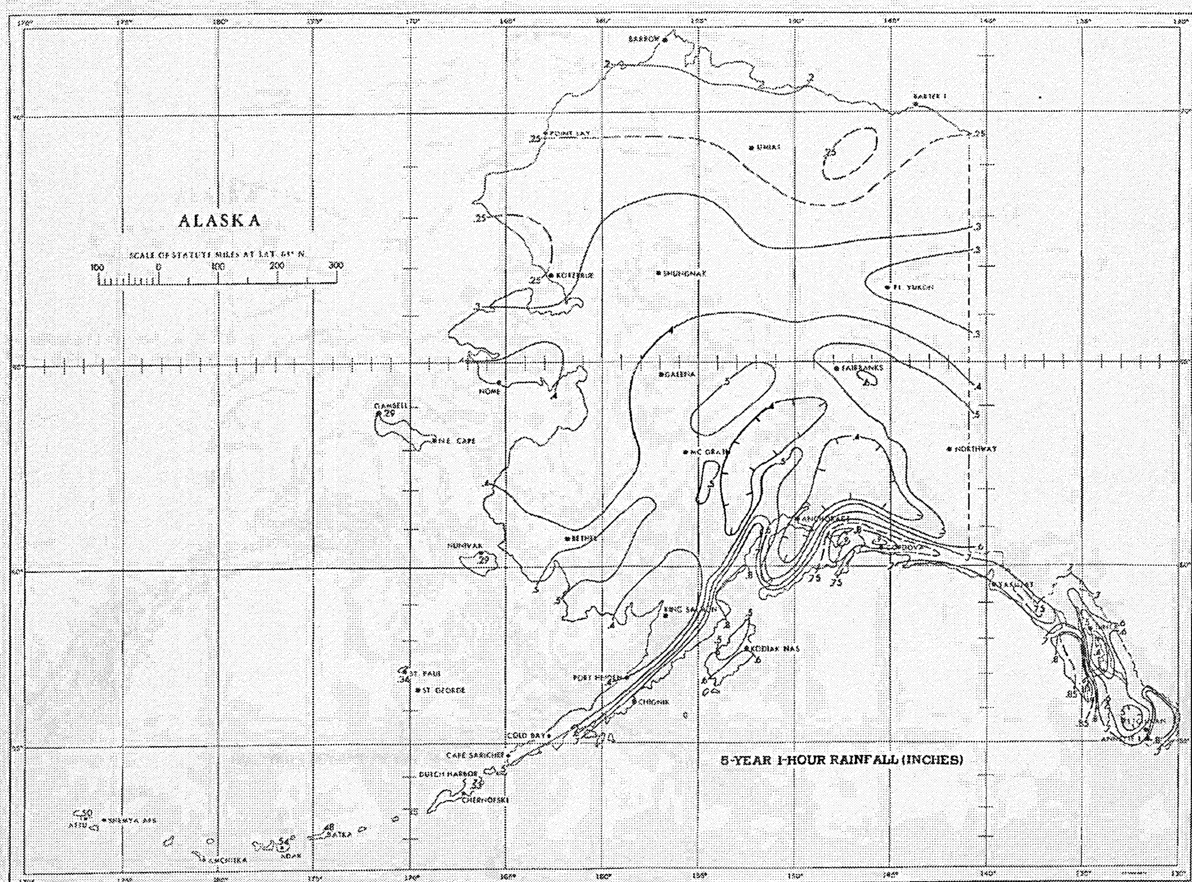


FIGURE 3-20.—5-yr. 1-hr. rainfall (in.).

10yr 1h

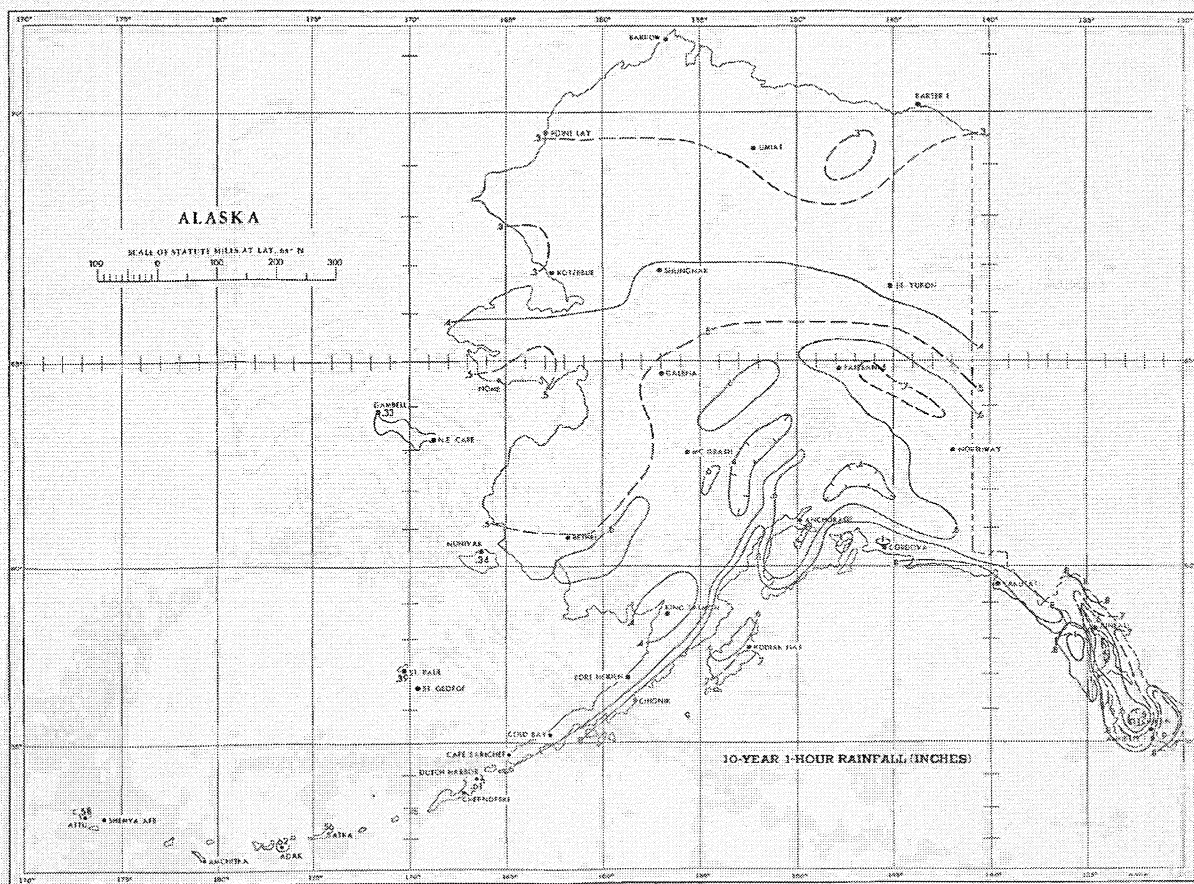


FIGURE 3-21.—10-yr. 1-hr. rainfall (in.).

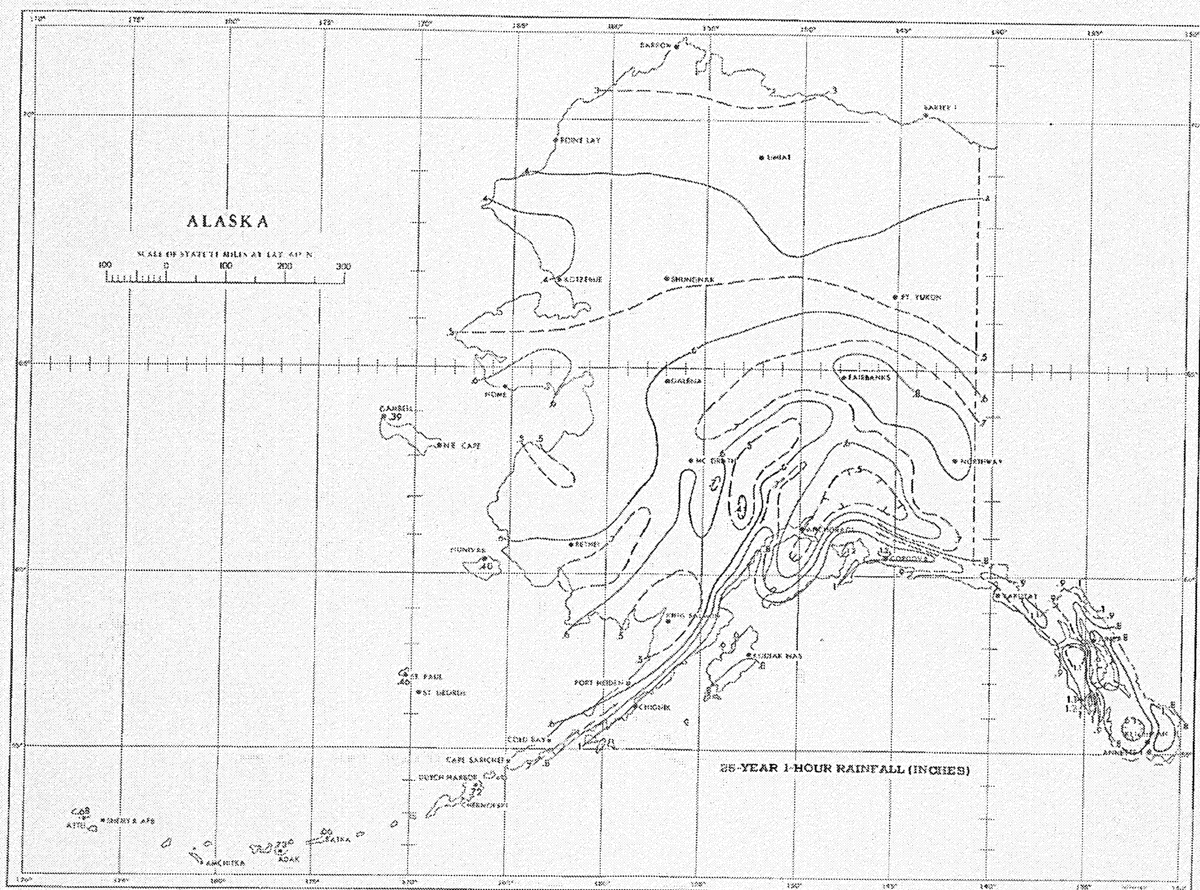


FIGURE 3-22.—25-yr. 1-hr. rainfall (in.).

50y 1h

.7 both

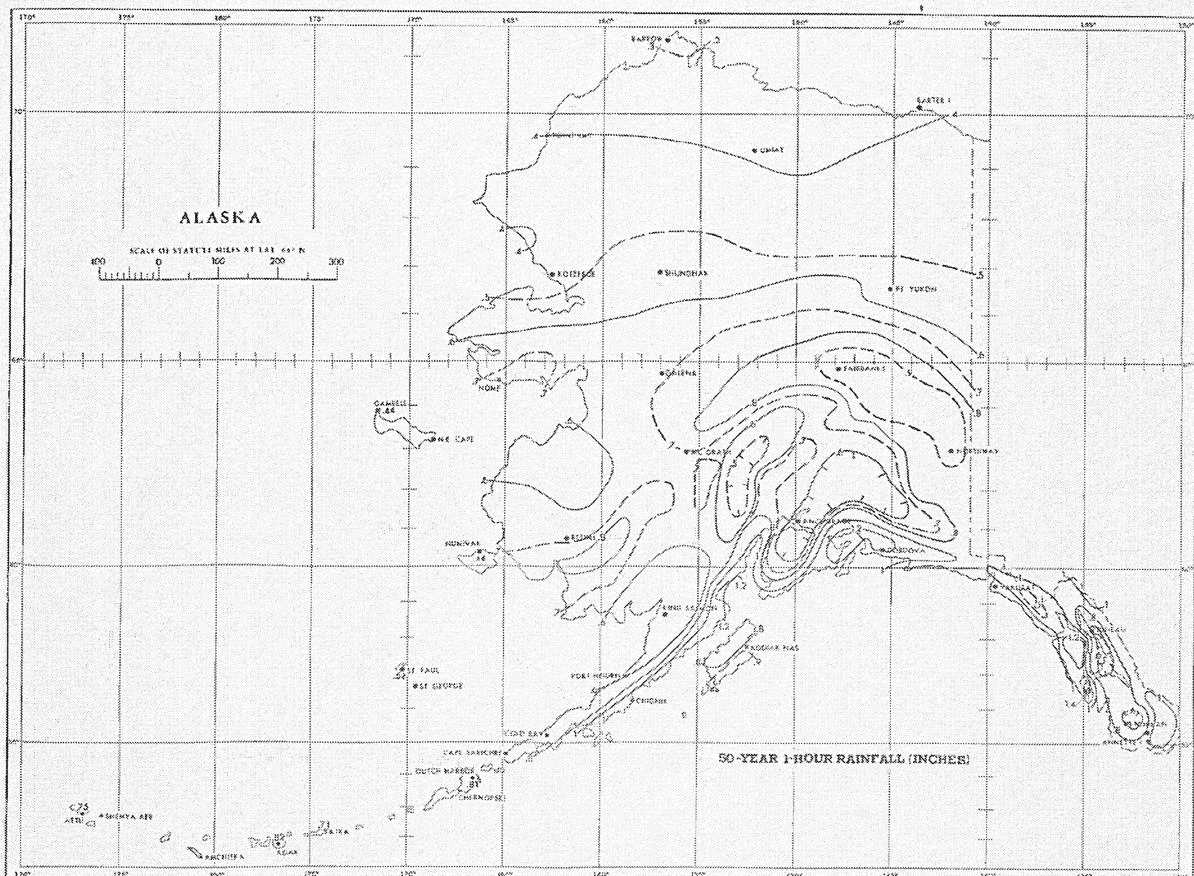


FIGURE 3-23.—50-yr. 1-hr. rainfall (in.).

33

100y 1h

.7 Rock
.8 Hurrah

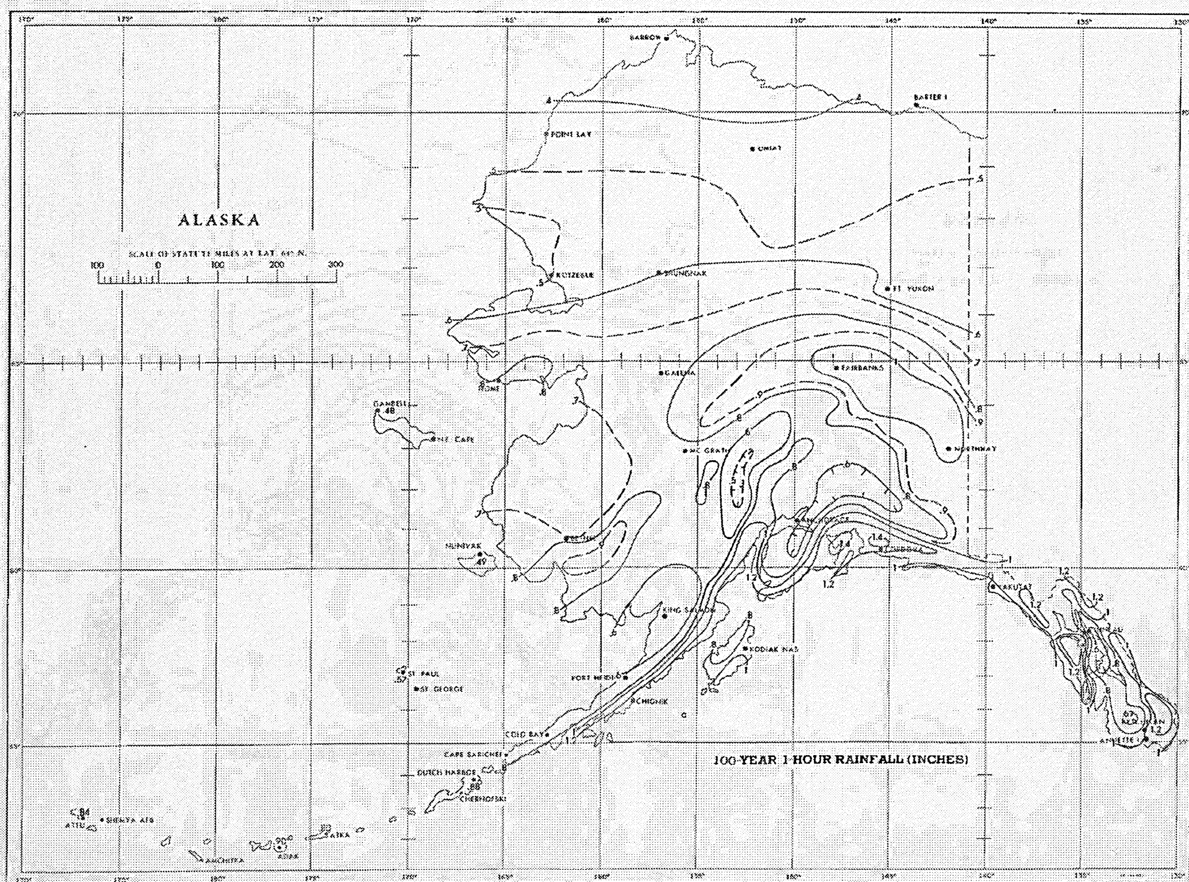


FIGURE 3-24.—100-yr. 1-hr. rainfall (in.).

1y 2h

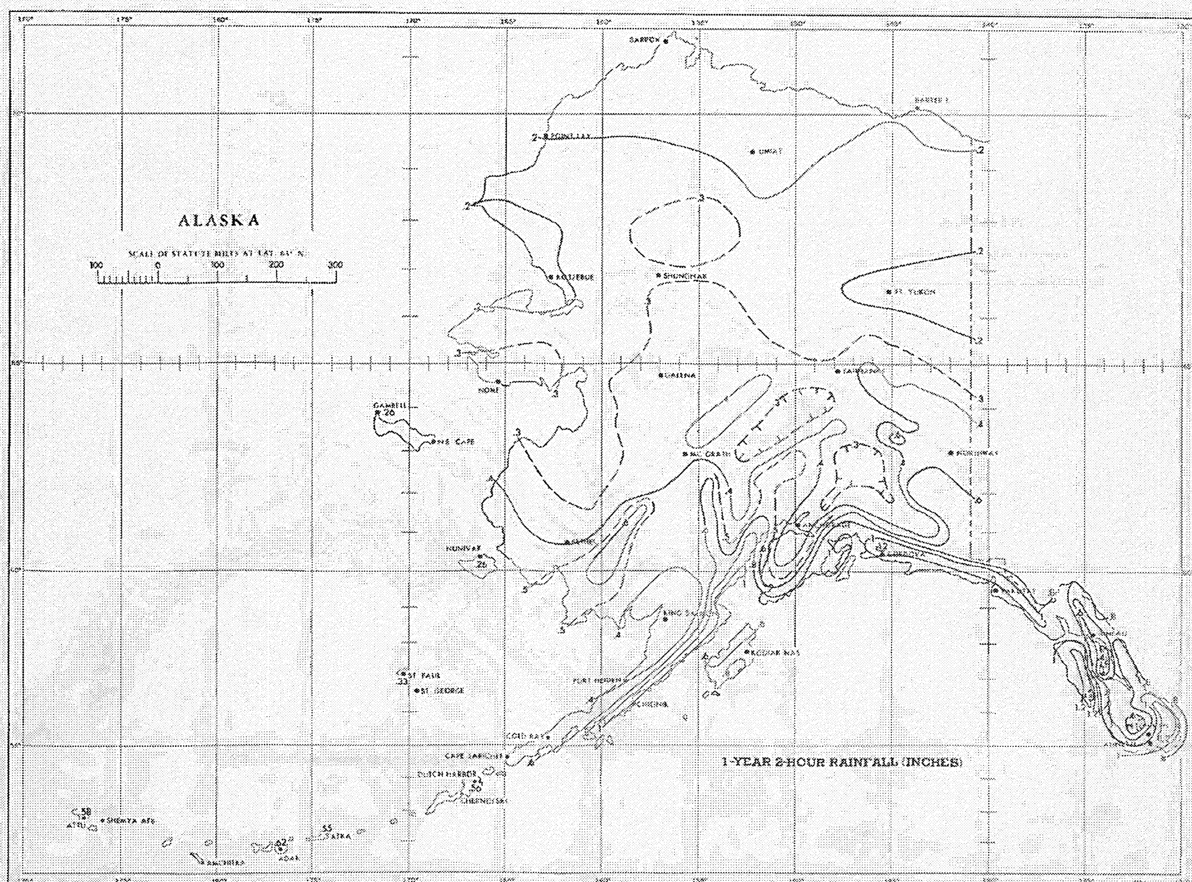


FIGURE 3-25.—1-yr. 2-hr. rainfall (in.).

2y 2h

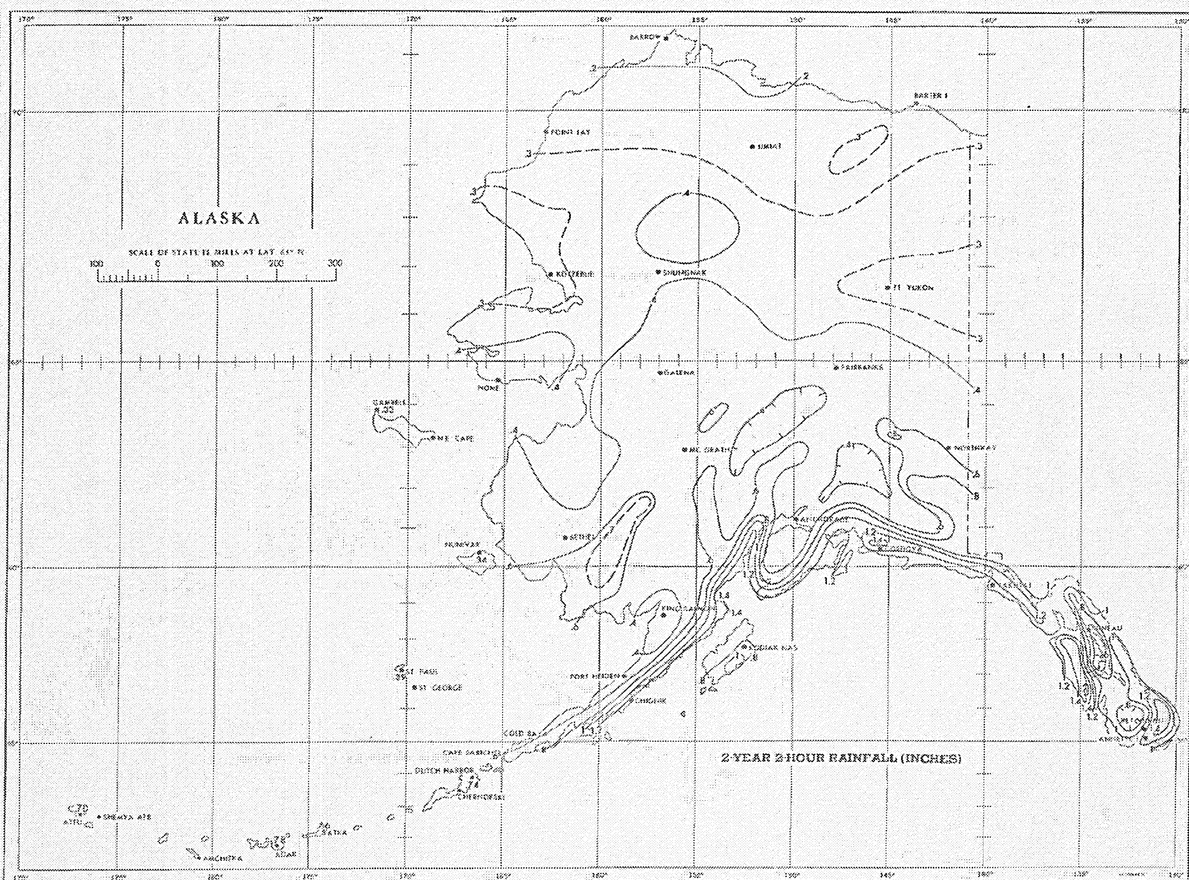


FIGURE 3-26.—2-yr. 2-hr. rainfall (in.).

5y 2h

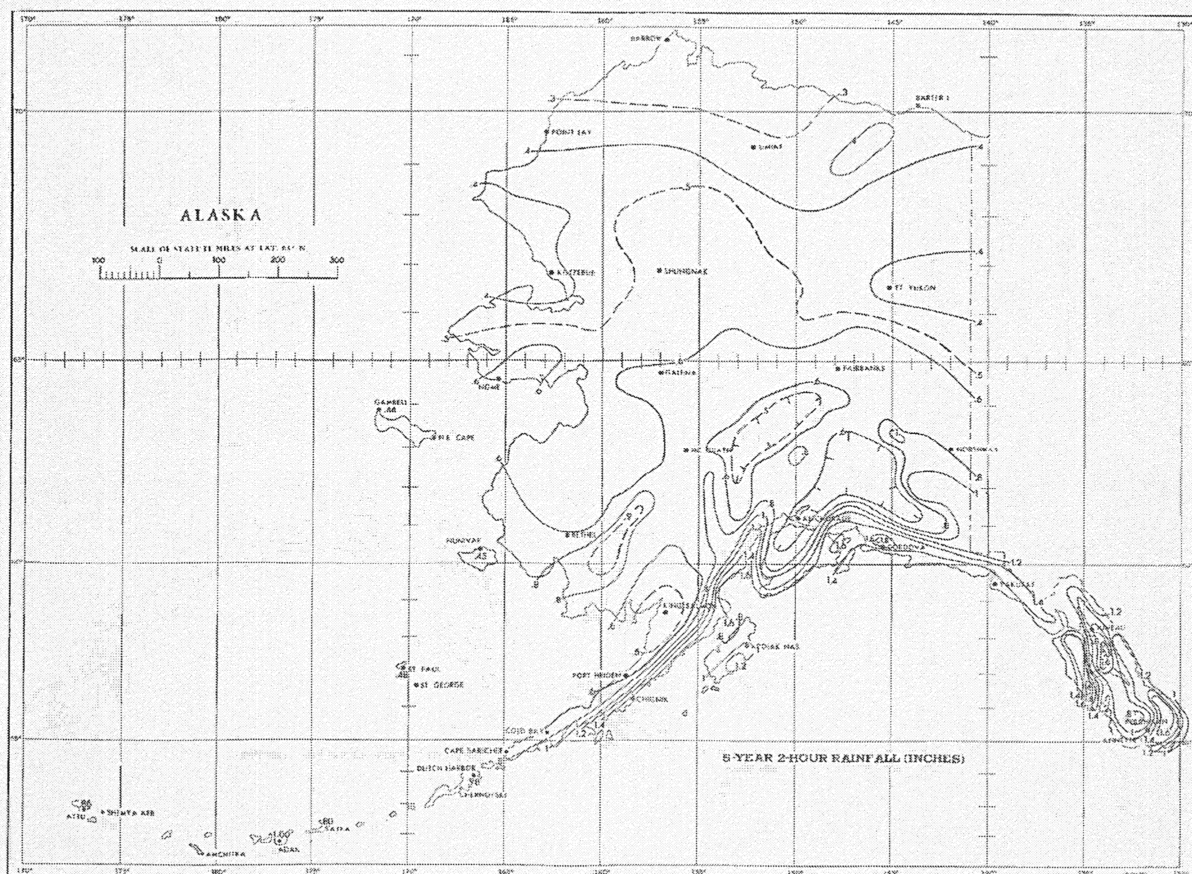


FIGURE 3-27.—5-yr. 2-hr. rainfall (in.).

10y 2hr

.5 Rock
.75 Hurrah

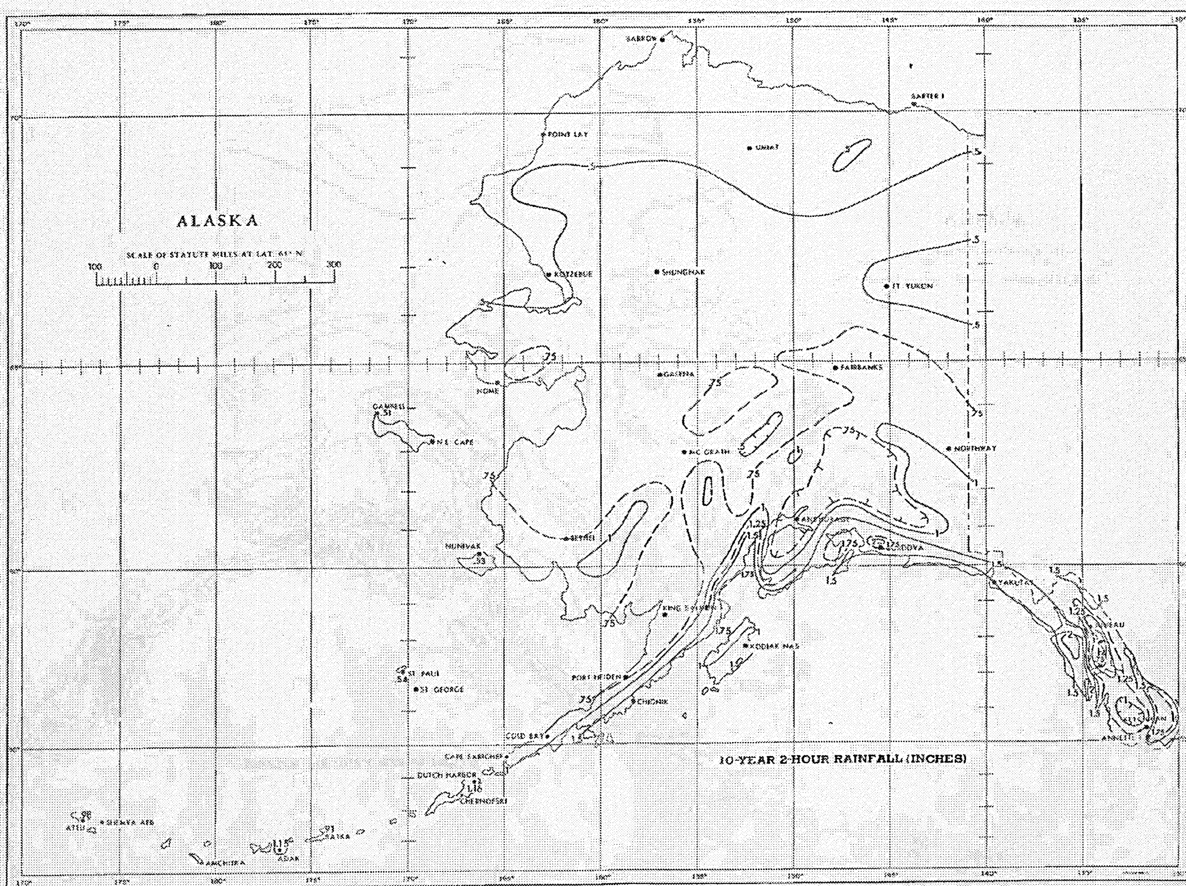


FIGURE 3-28.—10-yr. 2-hr. rainfall (in.).

25y 2h

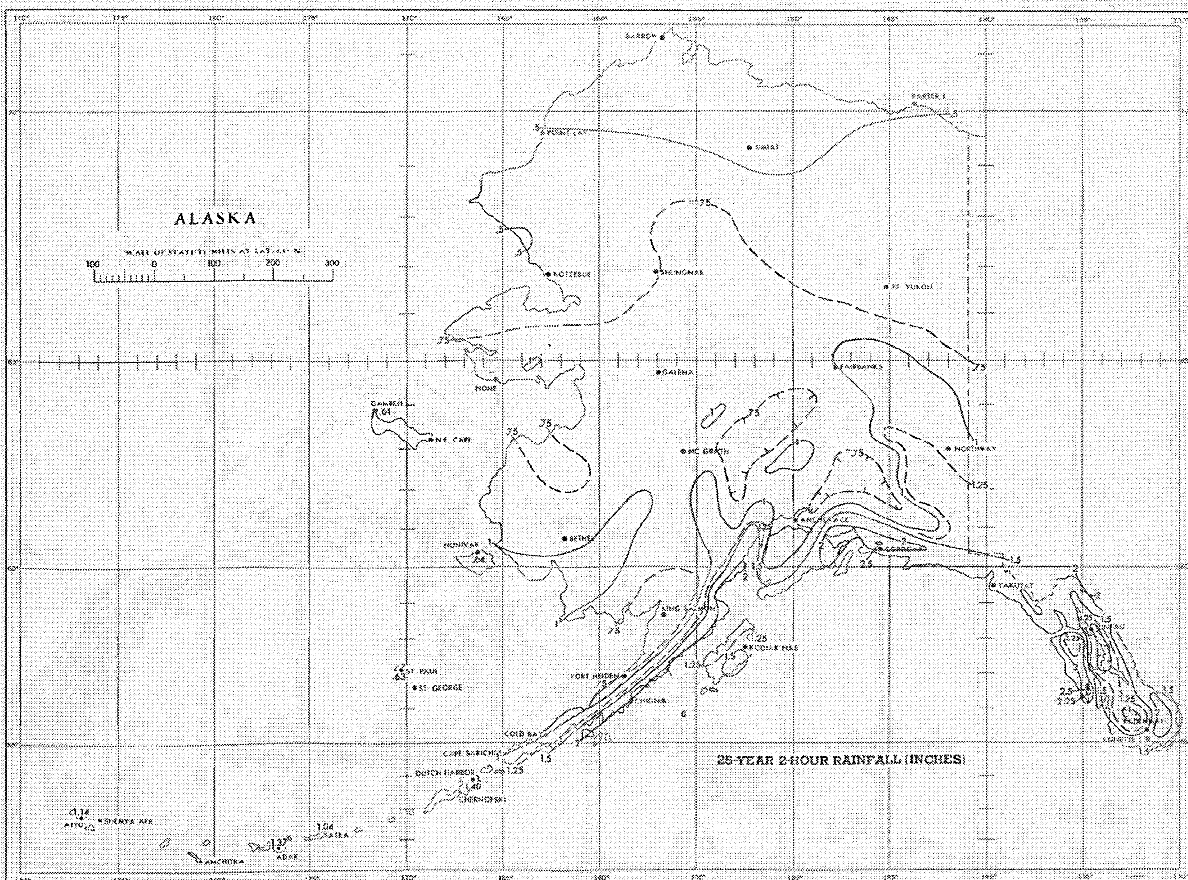


FIGURE 3-29.—25-yr. 2-hr. rainfall (in.).

50y 2h

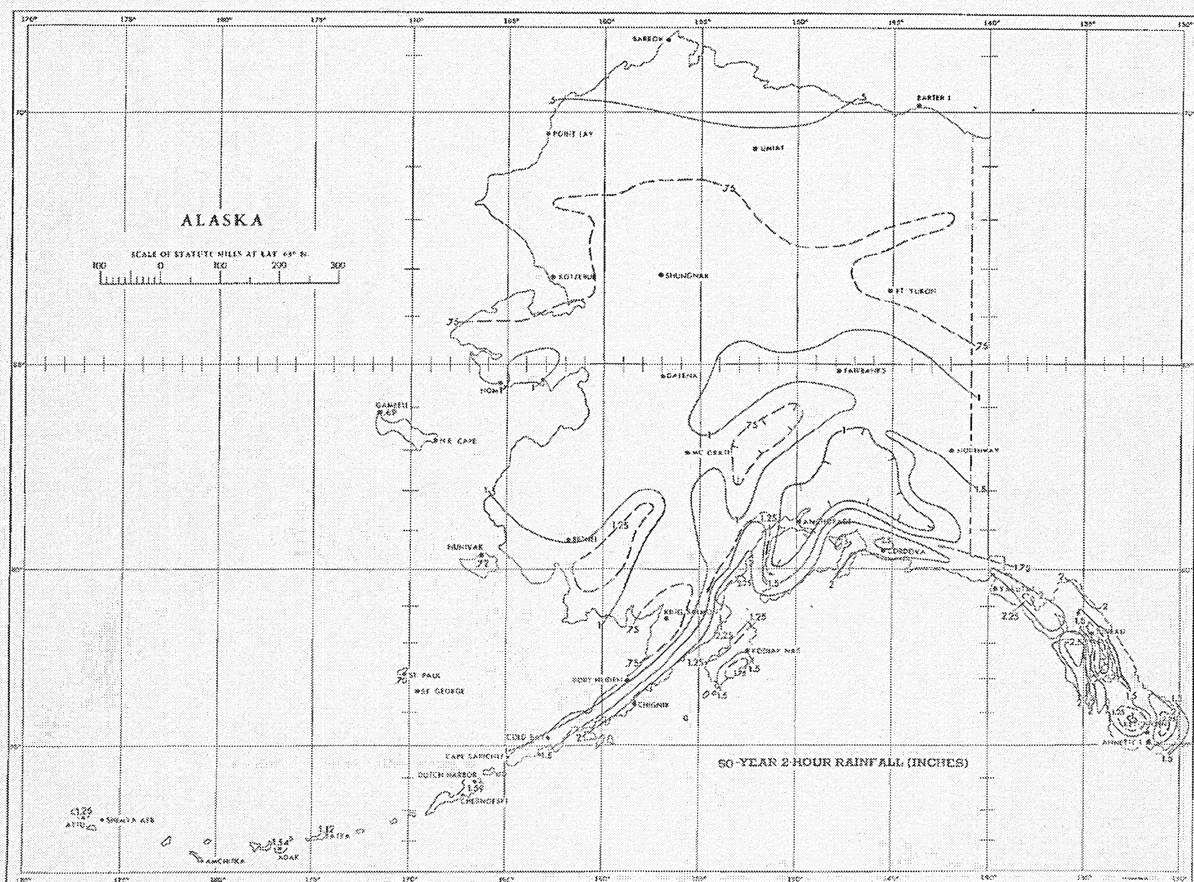


FIGURE 3-30.—50-yr. 2-hr. rainfall (in.).

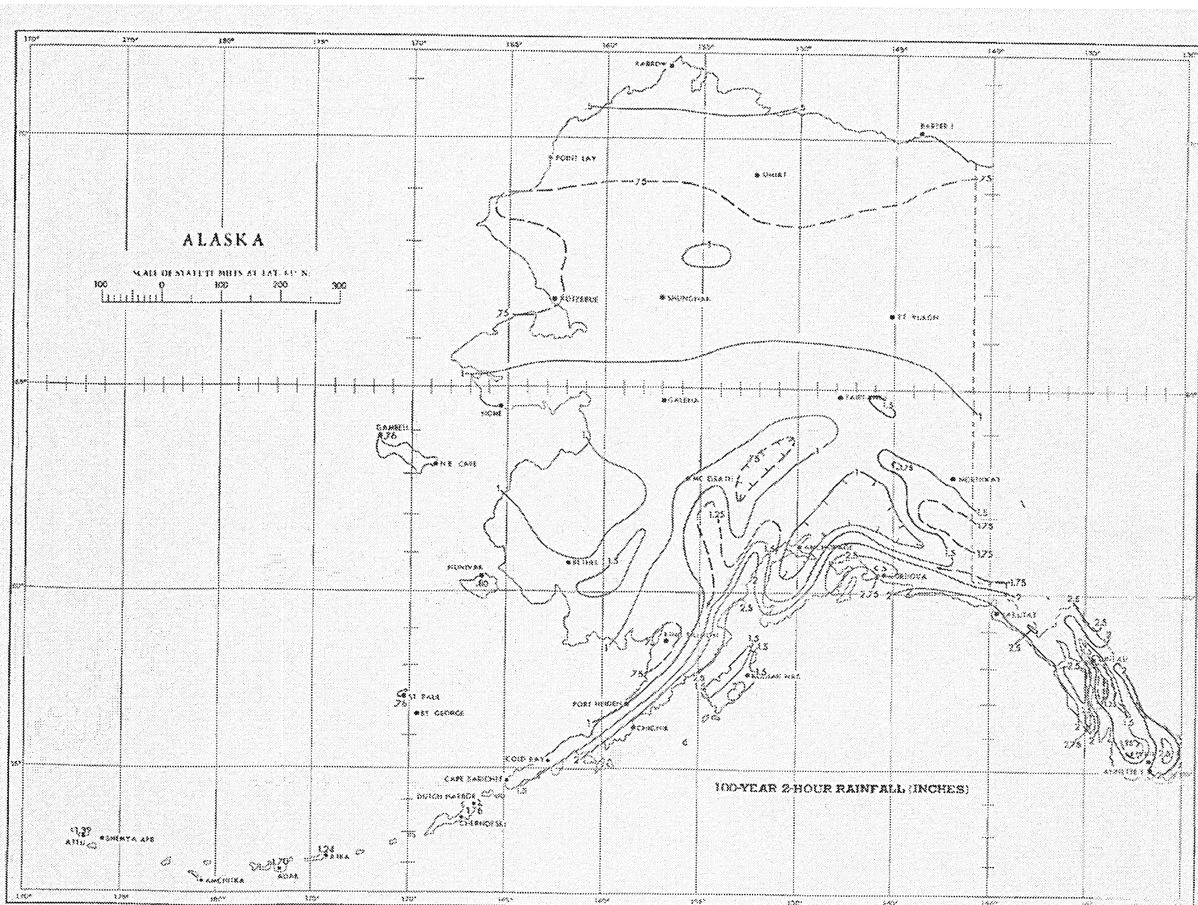


FIGURE 3-31.—100-yr. 2-hr. rainfall (in.).

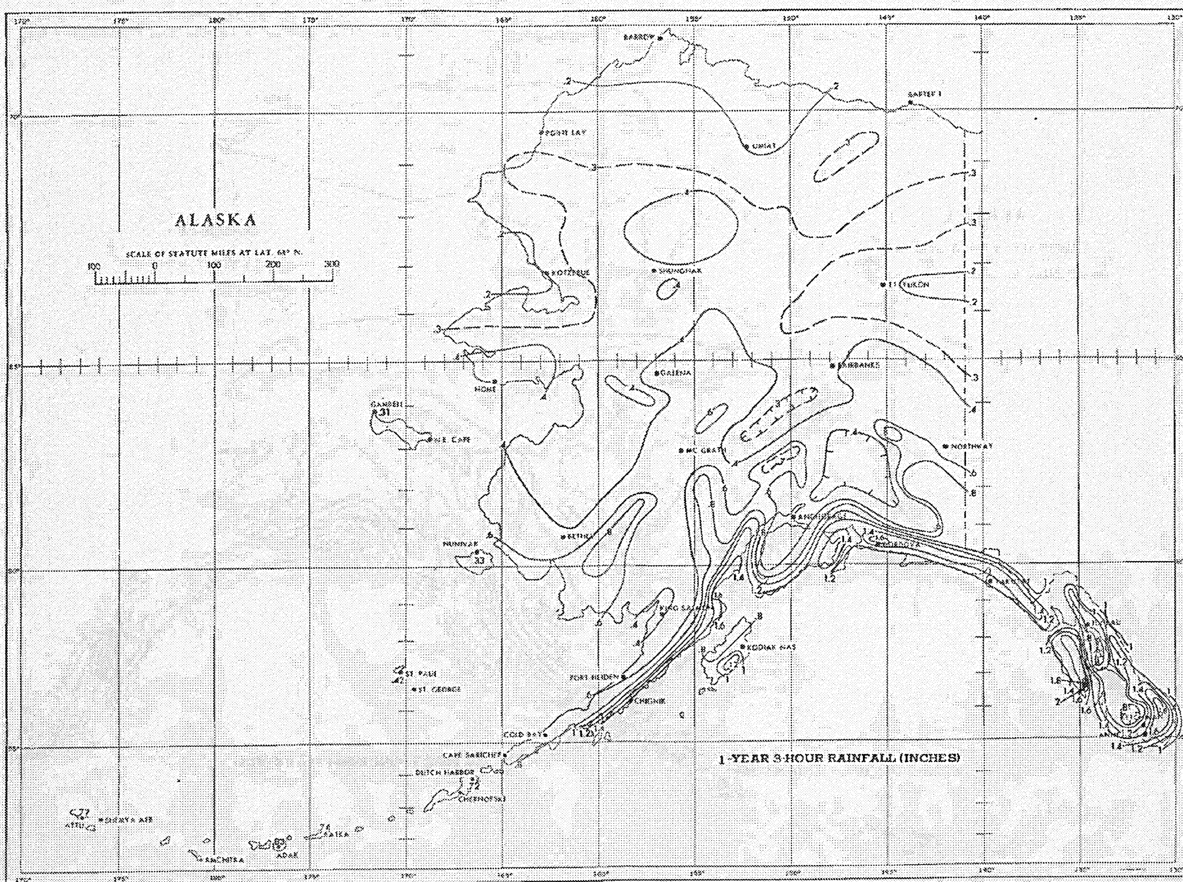


FIGURE 8-32.—1-yr. 3-hr. rainfall (in.).

2y 3h

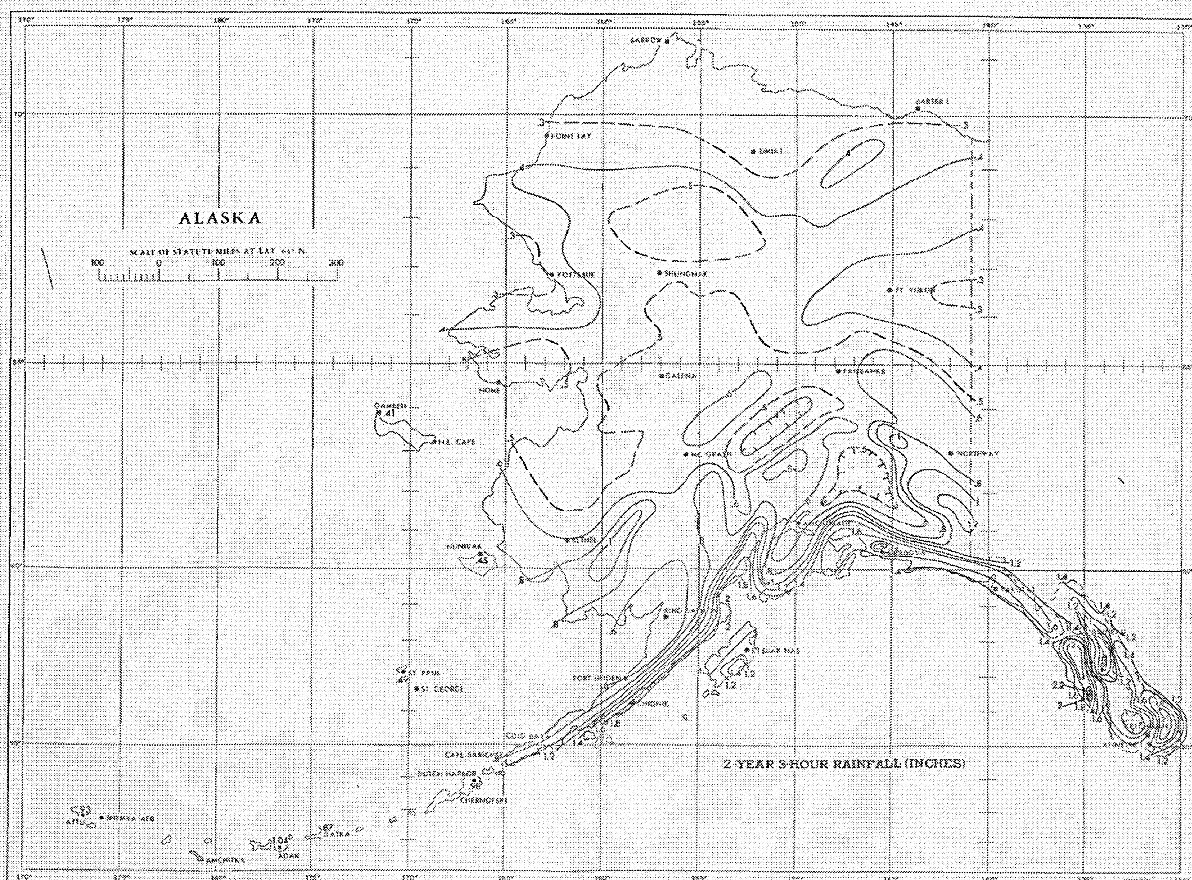


FIGURE 3-33.—2-yr. 3-hr. rainfall (in.).

5y 3h

.5 Both

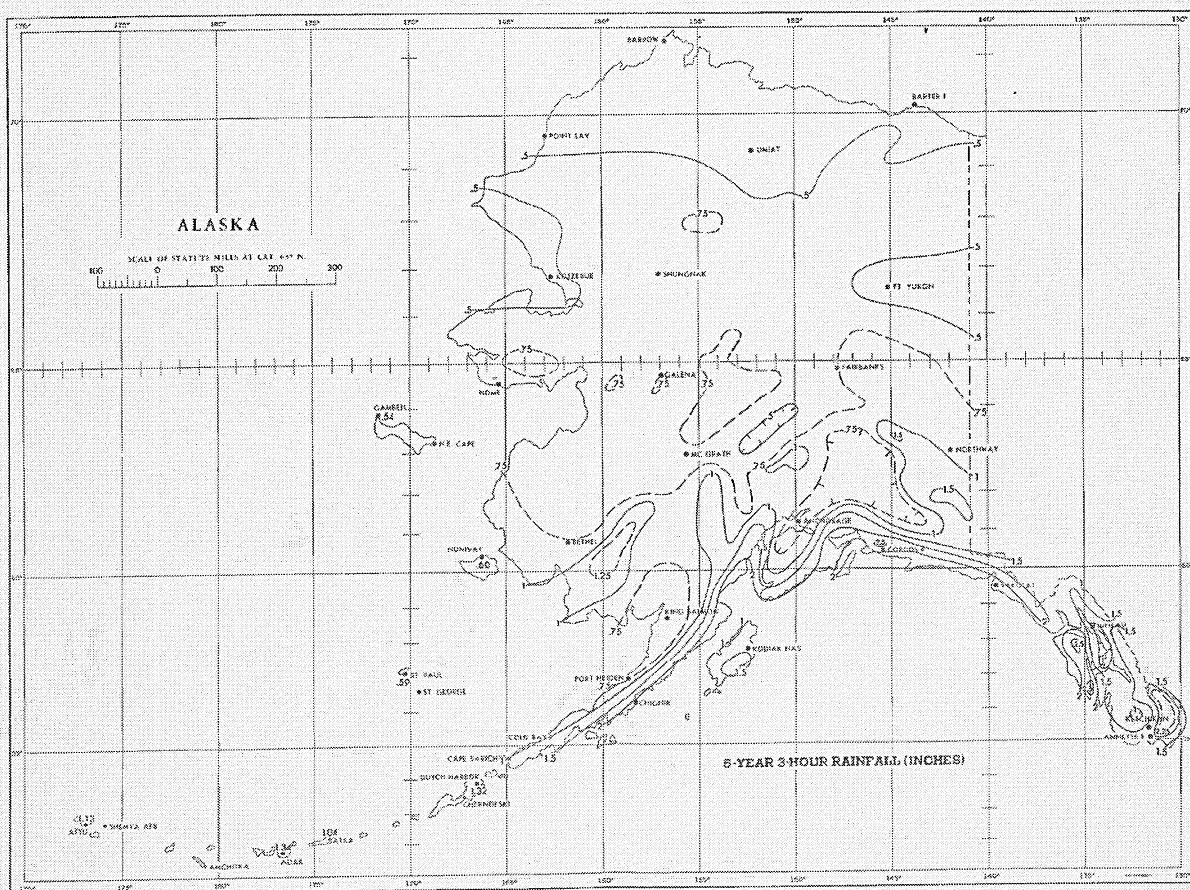


FIGURE 3-34.—5-yr. 3-hr. rainfall (in.).

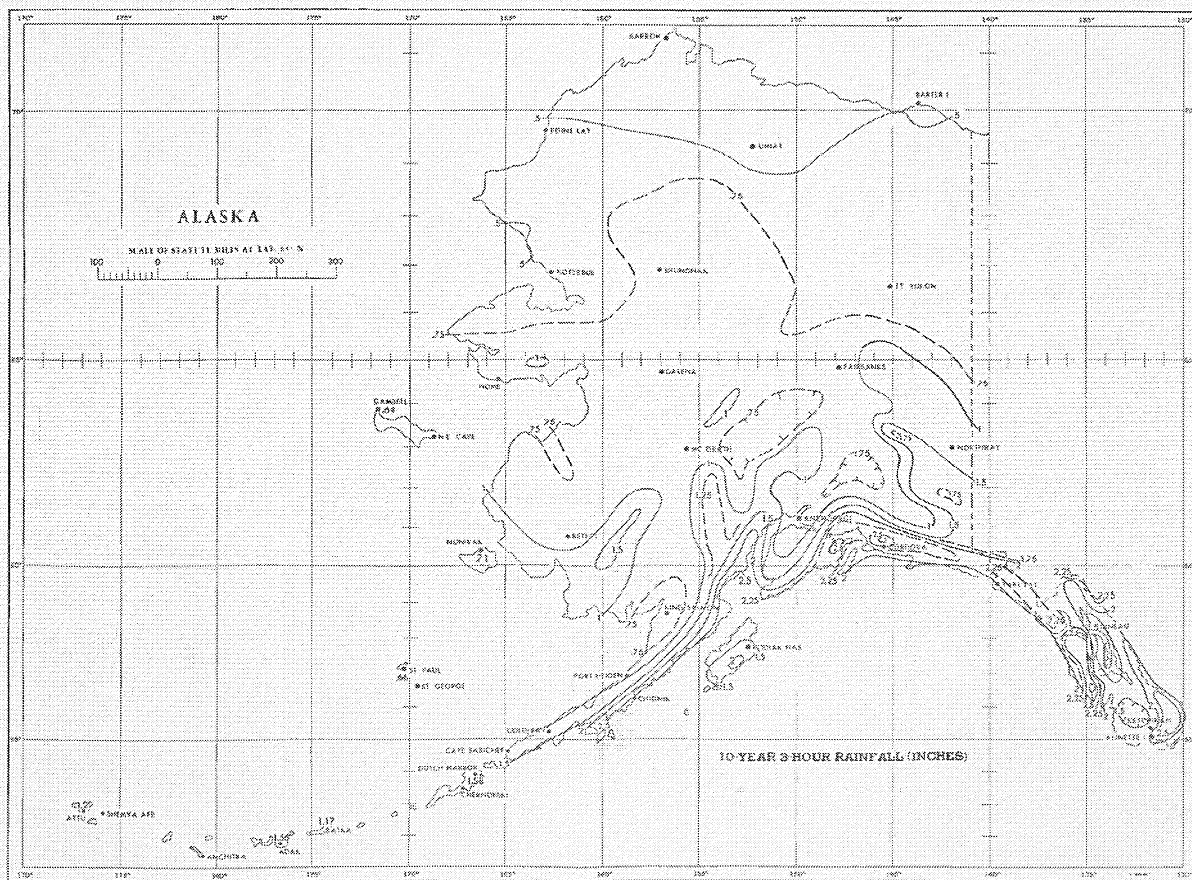


FIGURE 3-35.—10-yr. 3-hr. rainfall (in.).

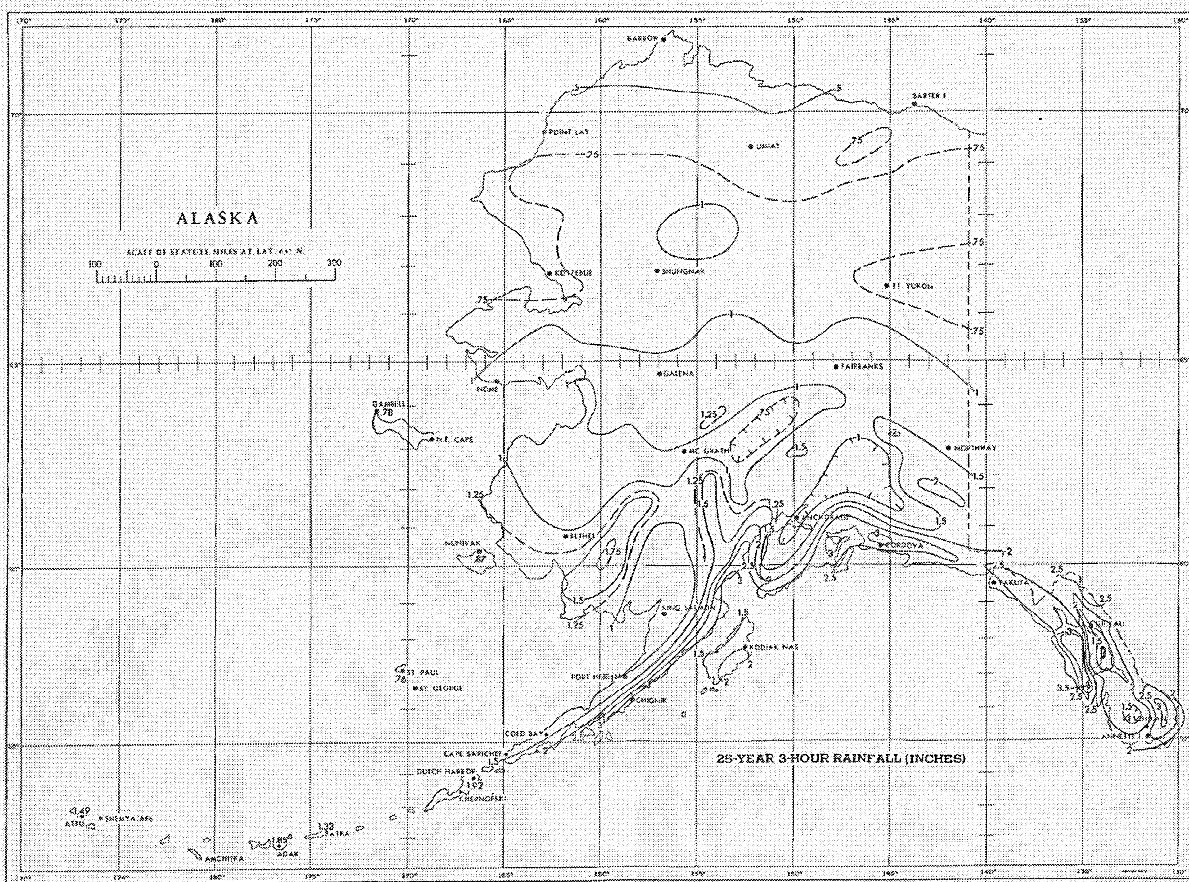


FIGURE 3-36.—25-yr. 3-hr. rainfall (in.).

50y 3h

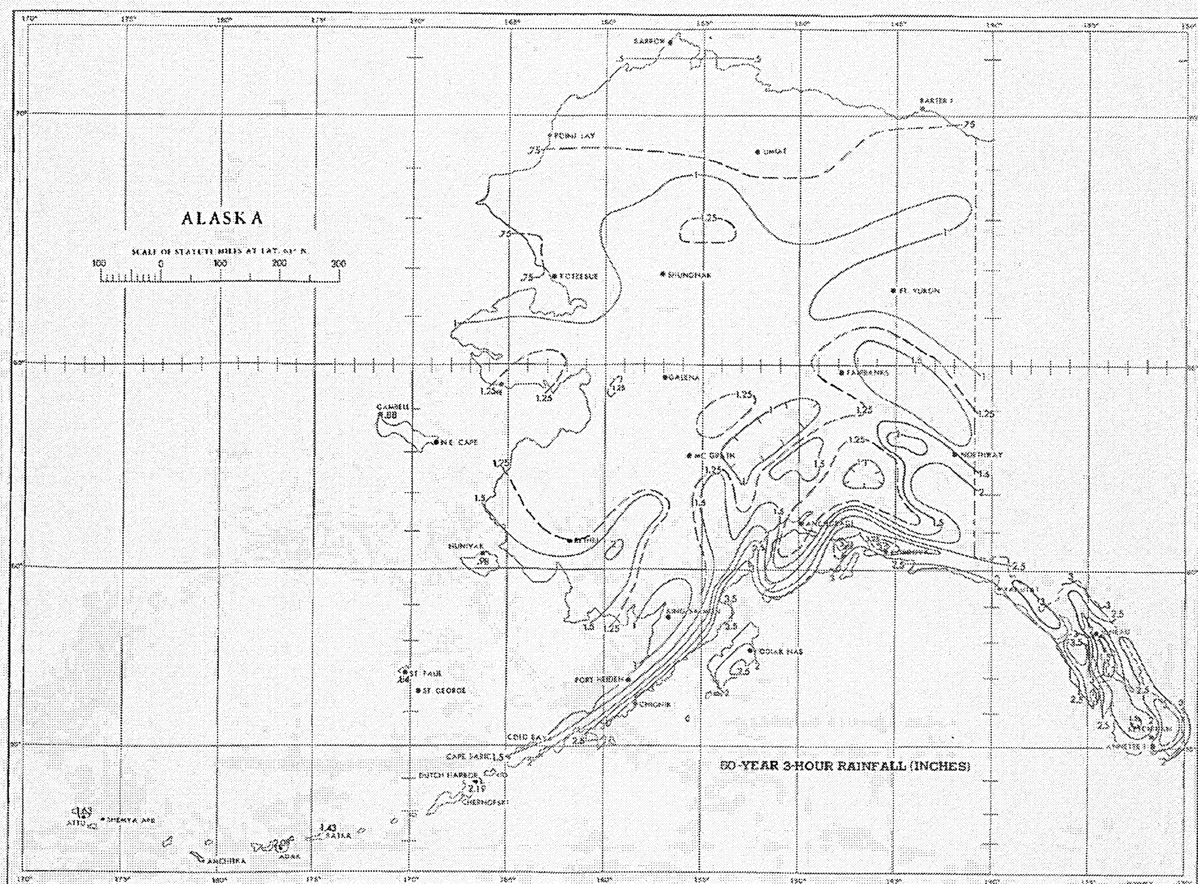


FIGURE 3-37.—50-yr. 3-hr. rainfall (in.).

100y 3h

1.5 Bom

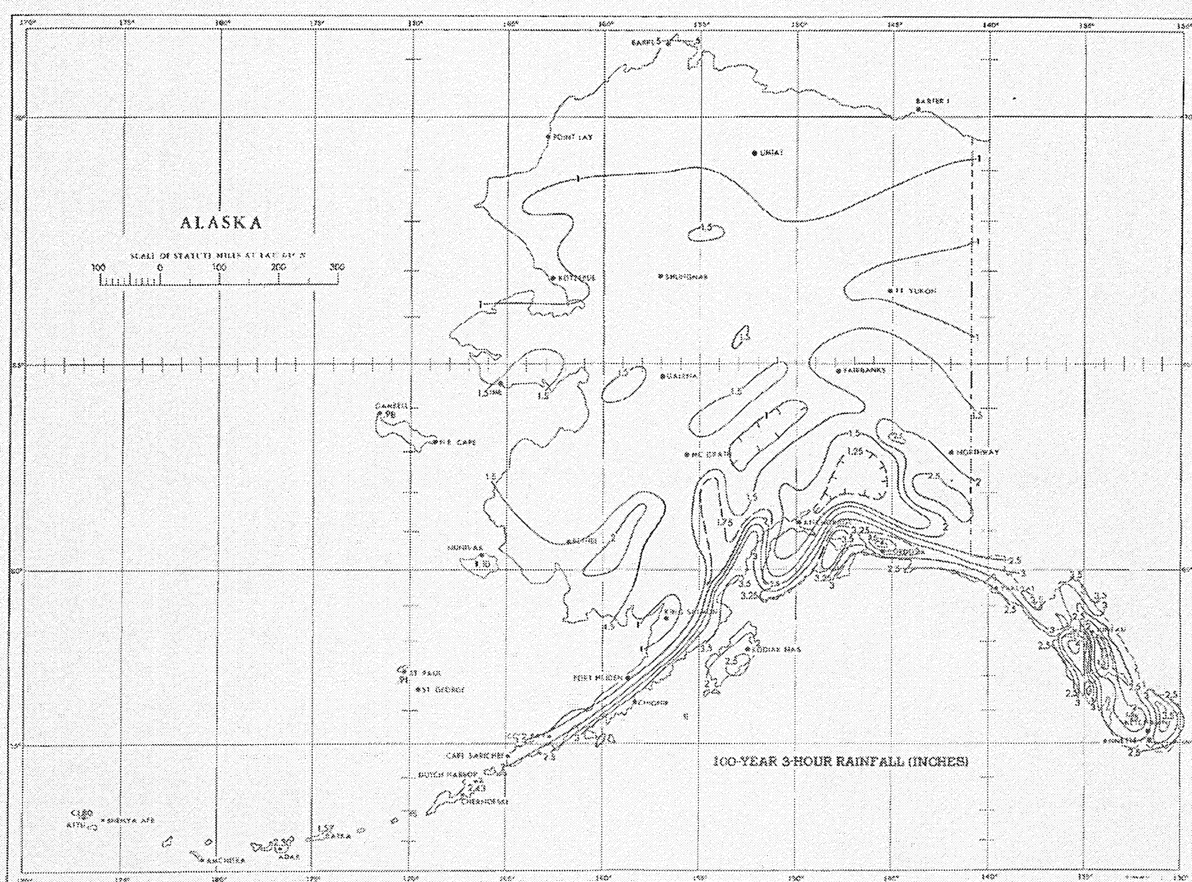


Figure 3-38.—100-yr. 3-hr. rainfall (in.).

1y-64

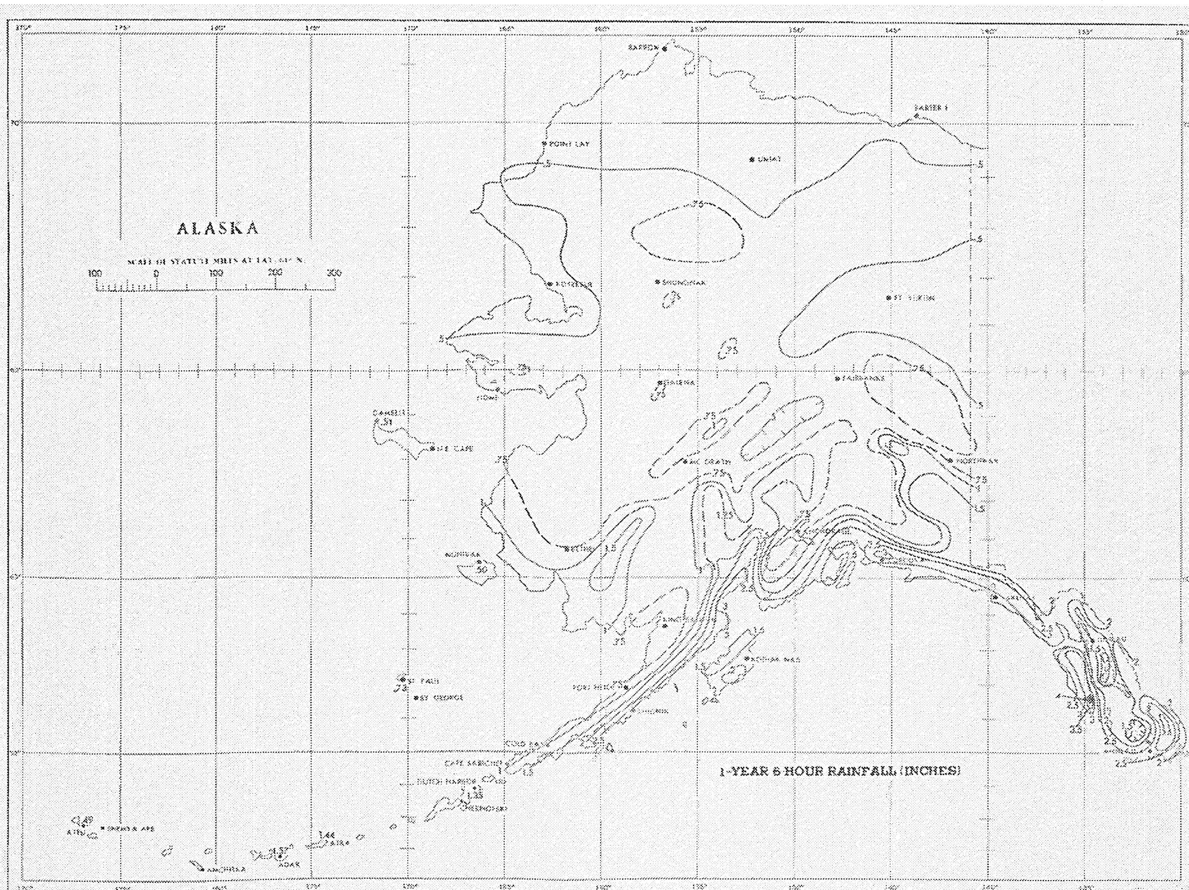


FIGURE 3-30.—1-yr. 6-hr. rainfall (in.).

2y 6h

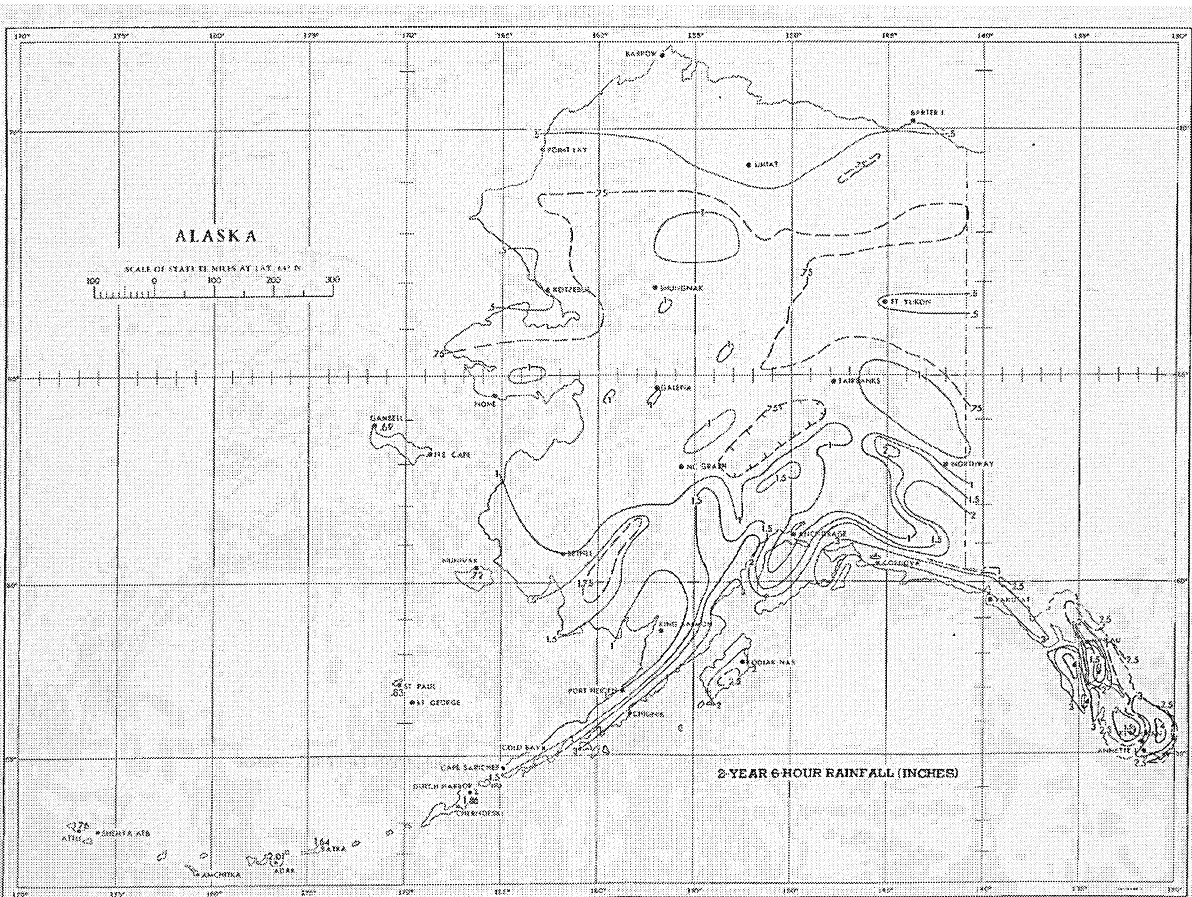


FIGURE 3-40.—2-yr. 6-hr. rainfall (in.).

5y 64

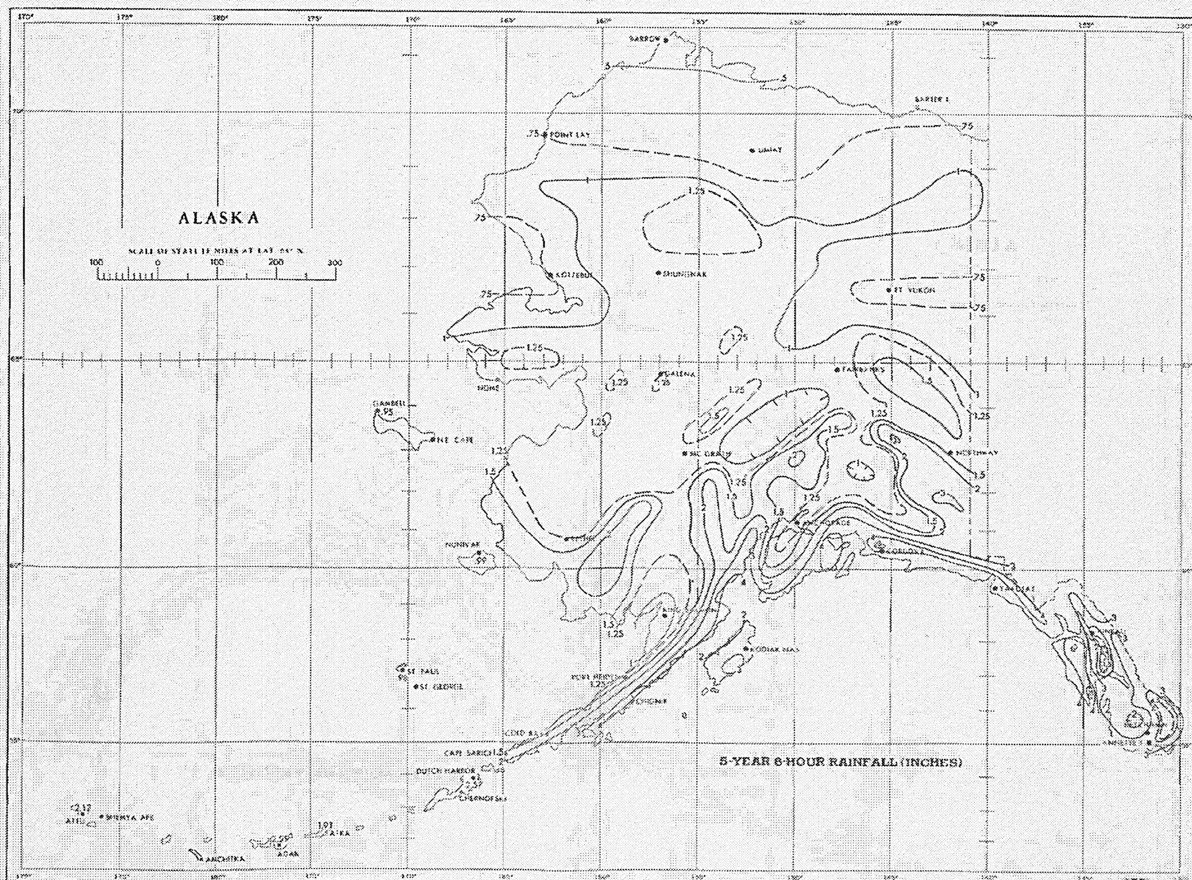


FIGURE 3-41.—5-yr. 6-hr. rainfall (in.).

10y 6h

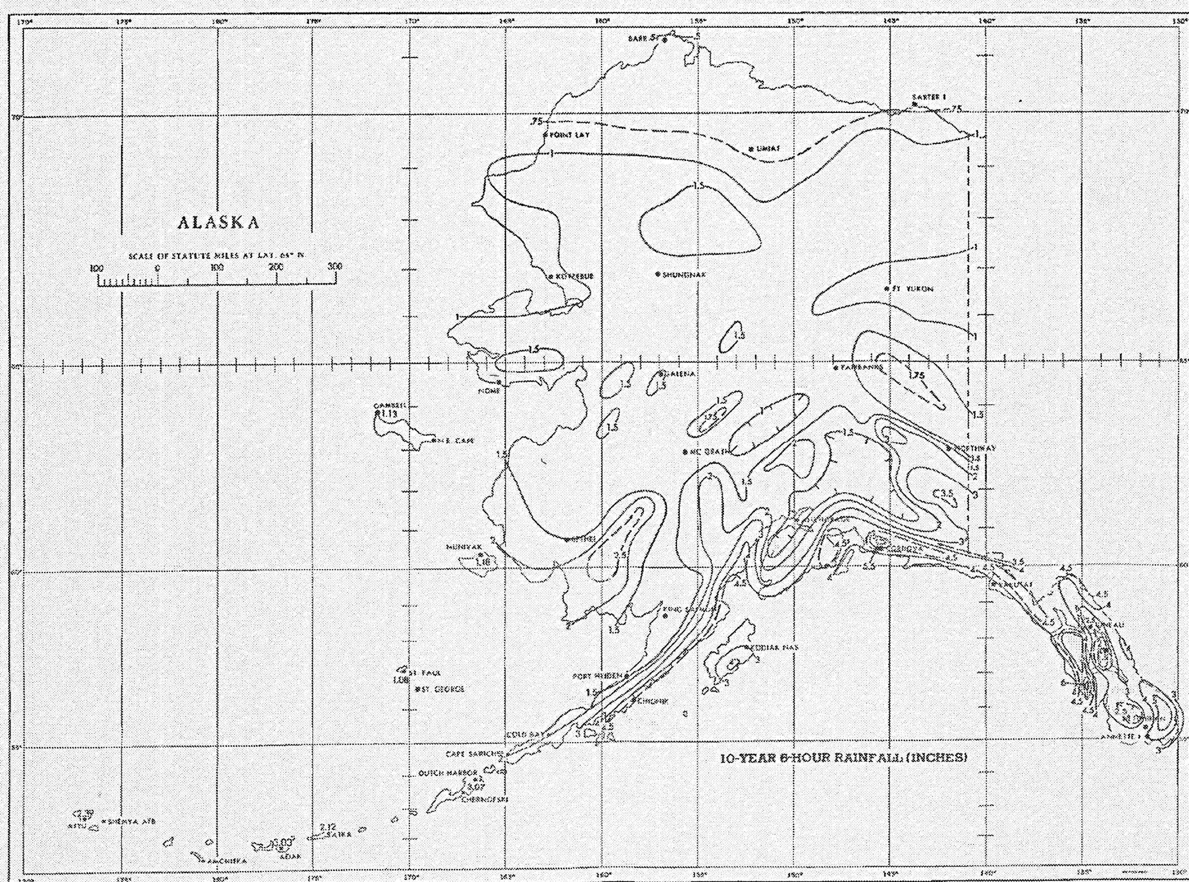


FIGURE 3-42.—10-yr. 6-hr. rainfall (in.).

25 y 6h

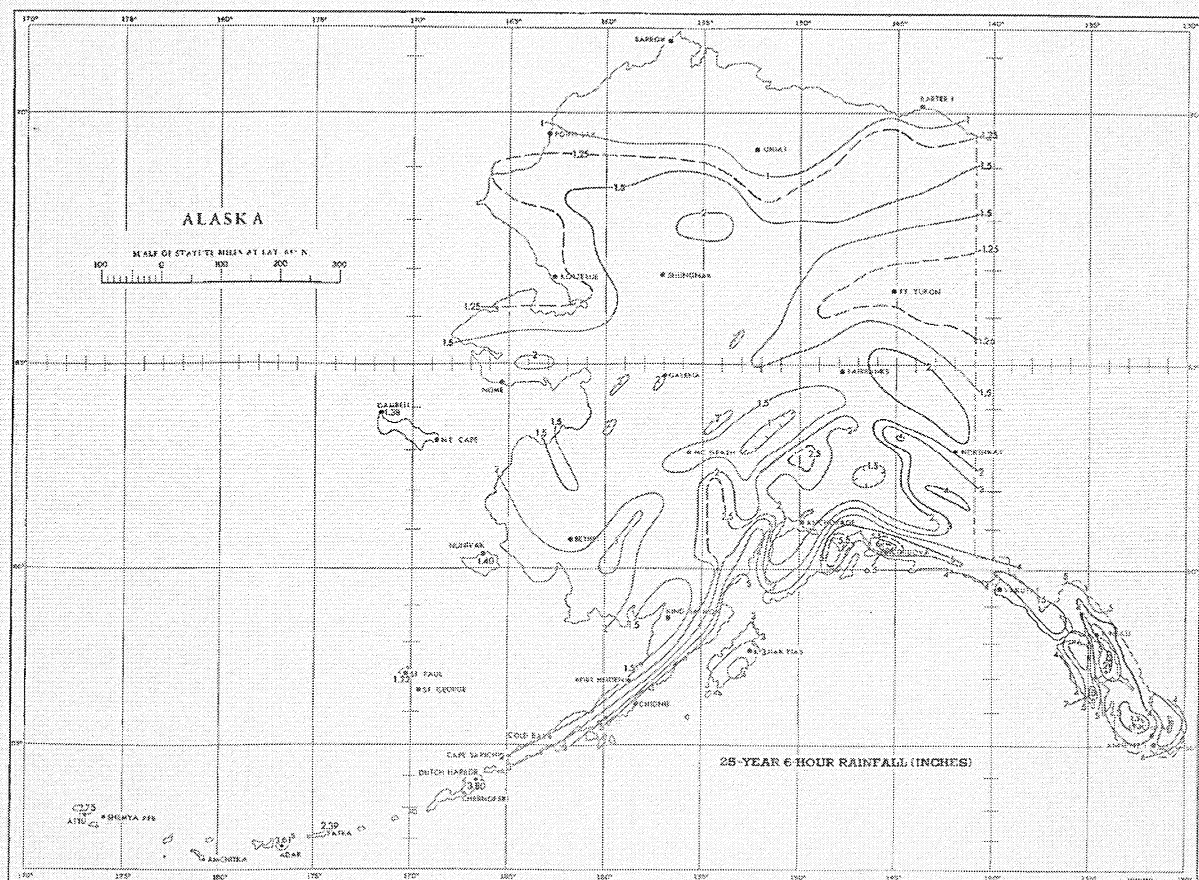


FIGURE 3-43.—25-yr. 6-hr. rainfall (in.).

100y6h

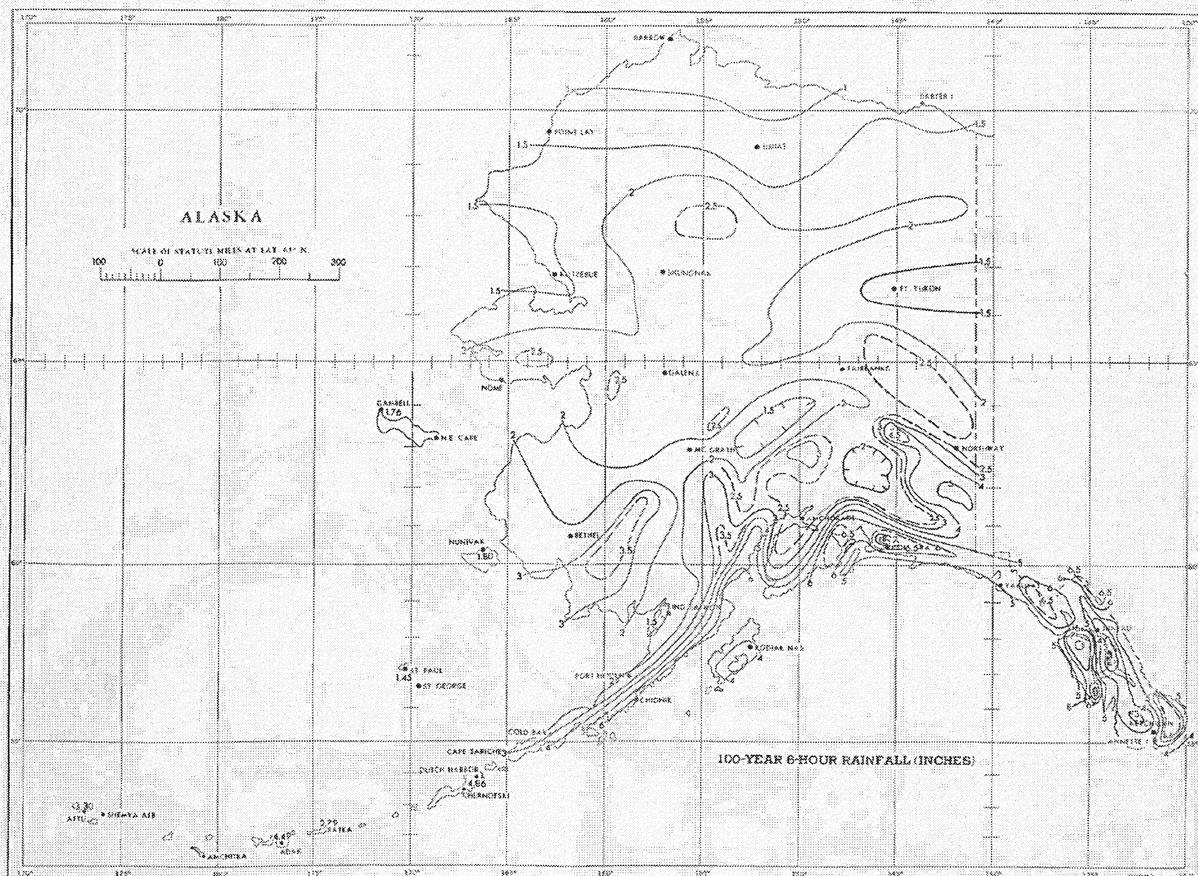


FIGURE 3-45.—100-yr. 6-hr. rainfall (in.).

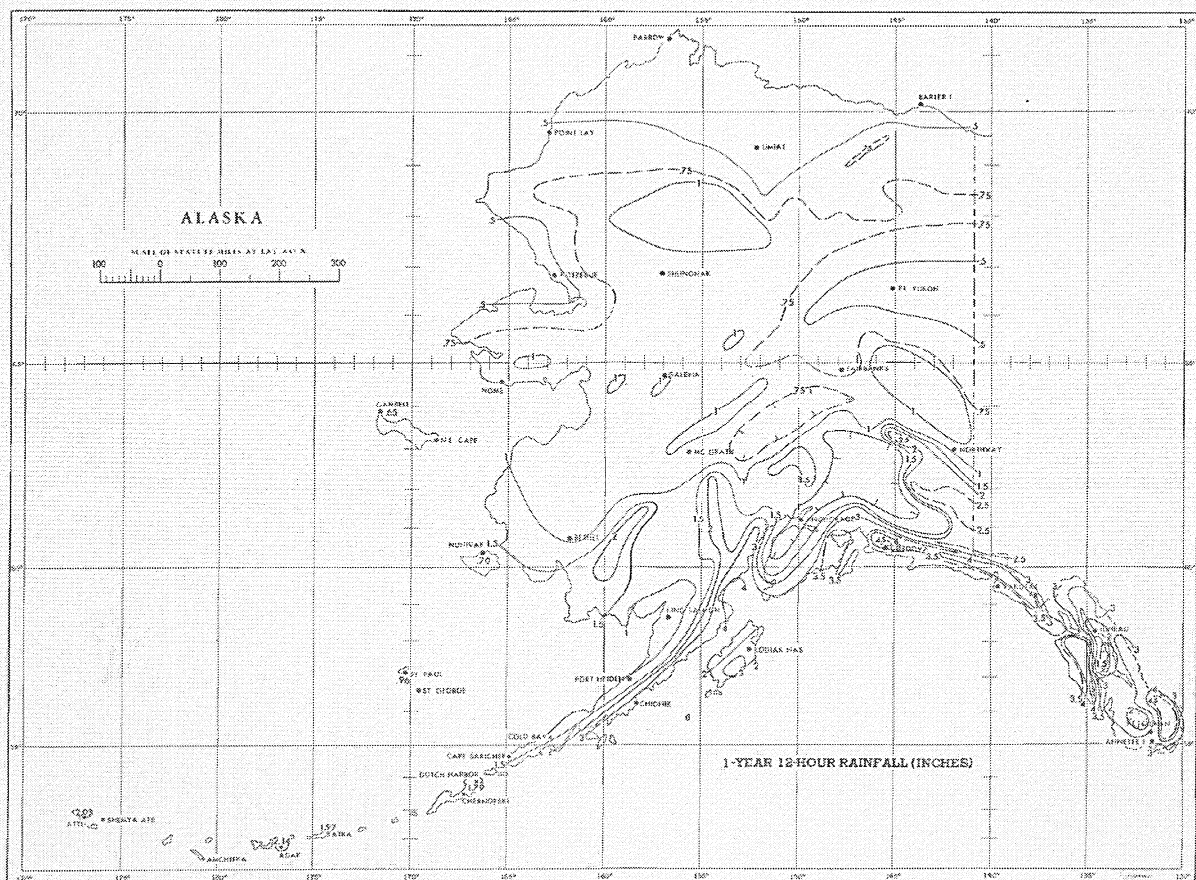


Figure 3-46.—1-yr. 12-hr. rainfall (in.).

2y 12h

1 Both

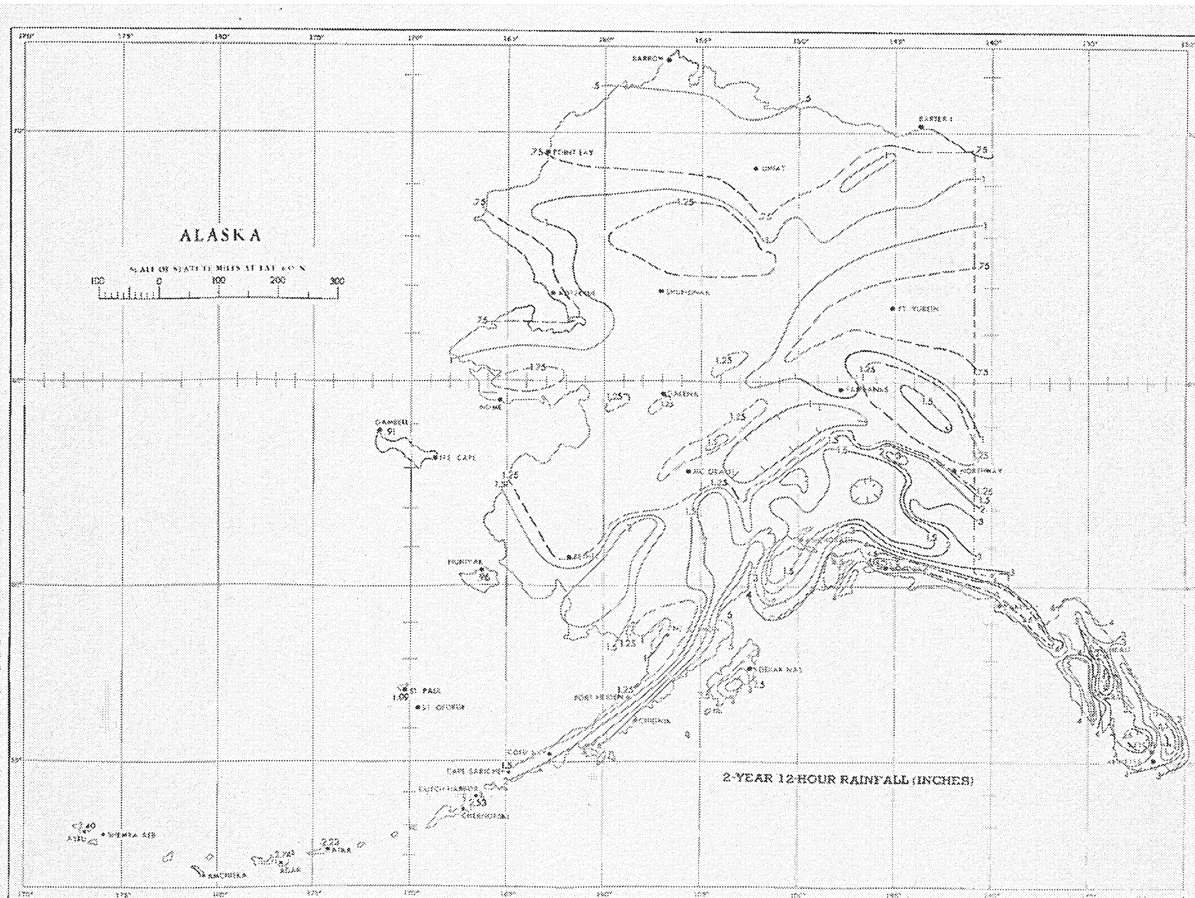


FIGURE 3-47.—2-yr. 12-hr. rainfall (in.).

5y 12h

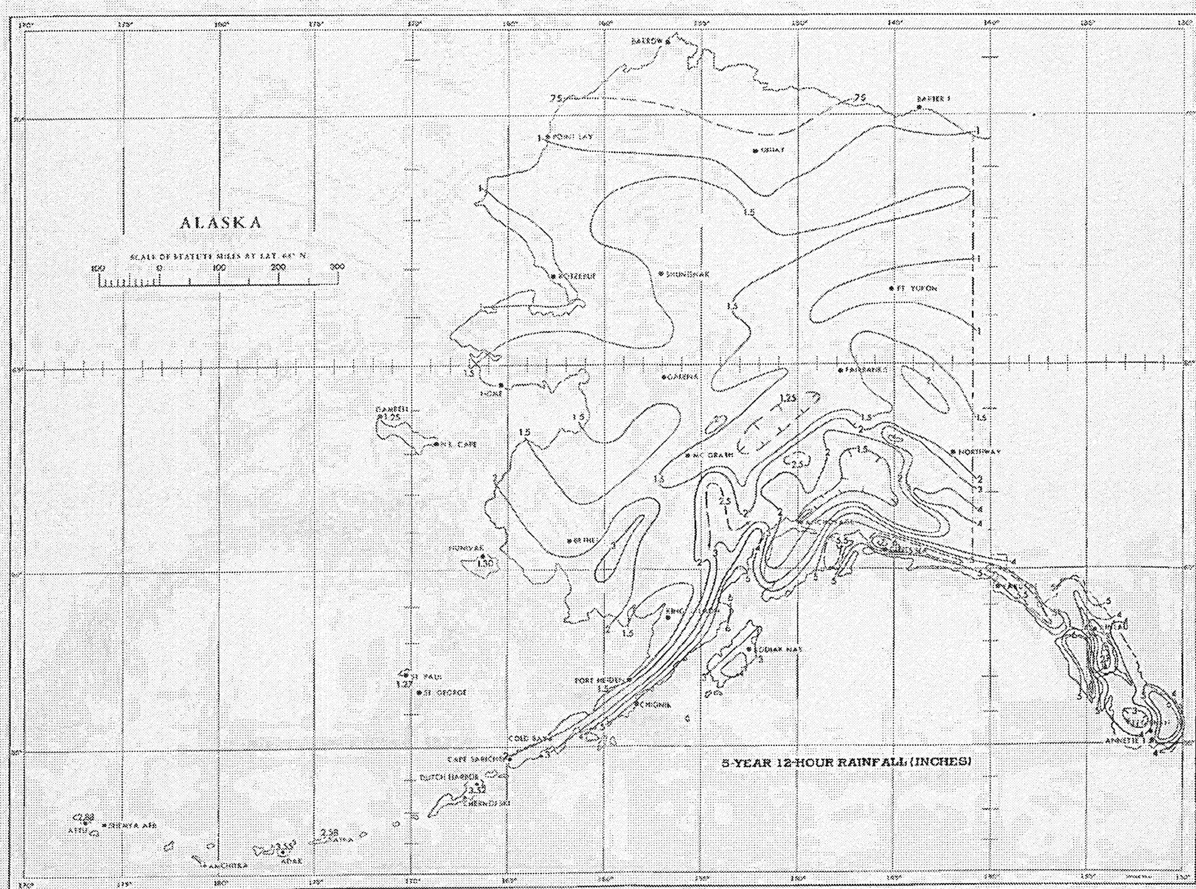


FIGURE 8-48.—5-yr. 12-hr. rainfall (in.).

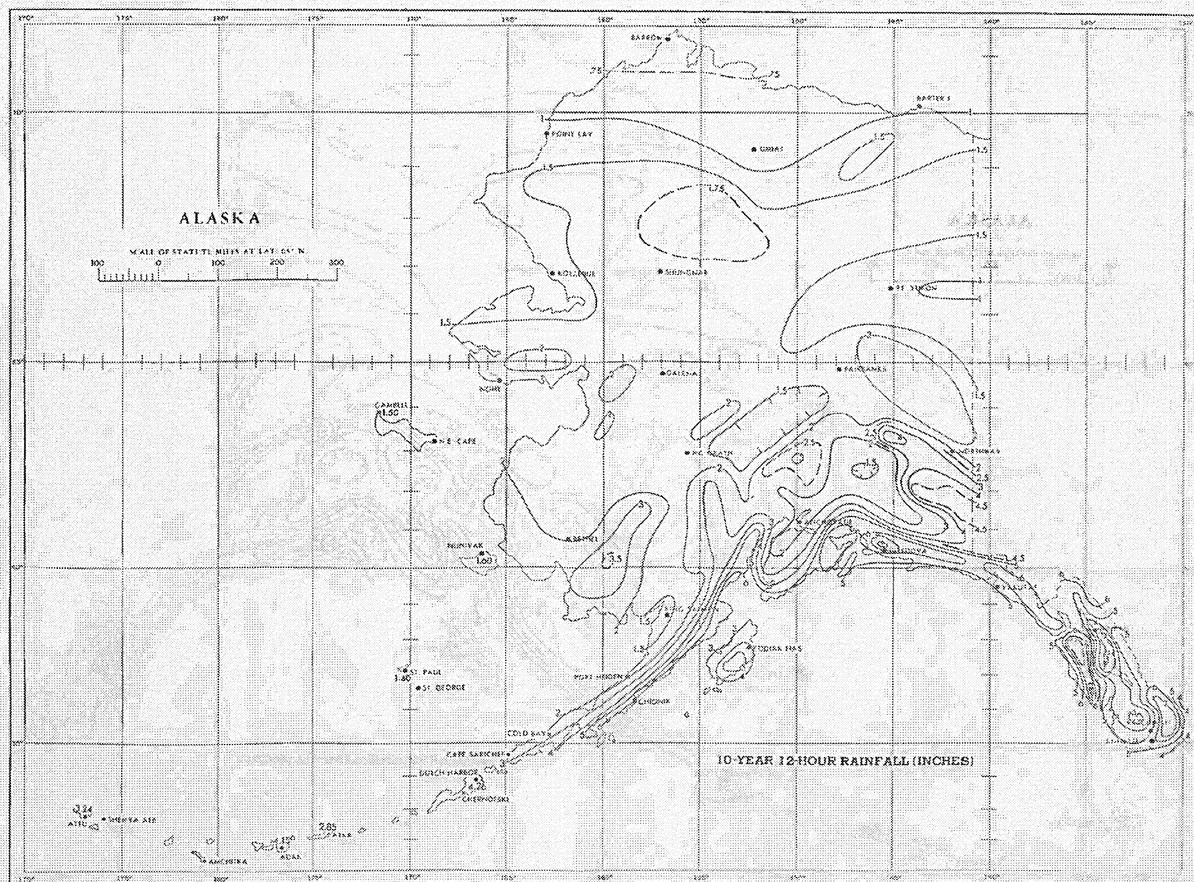


FIGURE 3-49.—10-yr. 12-hr. rainfall (in.).

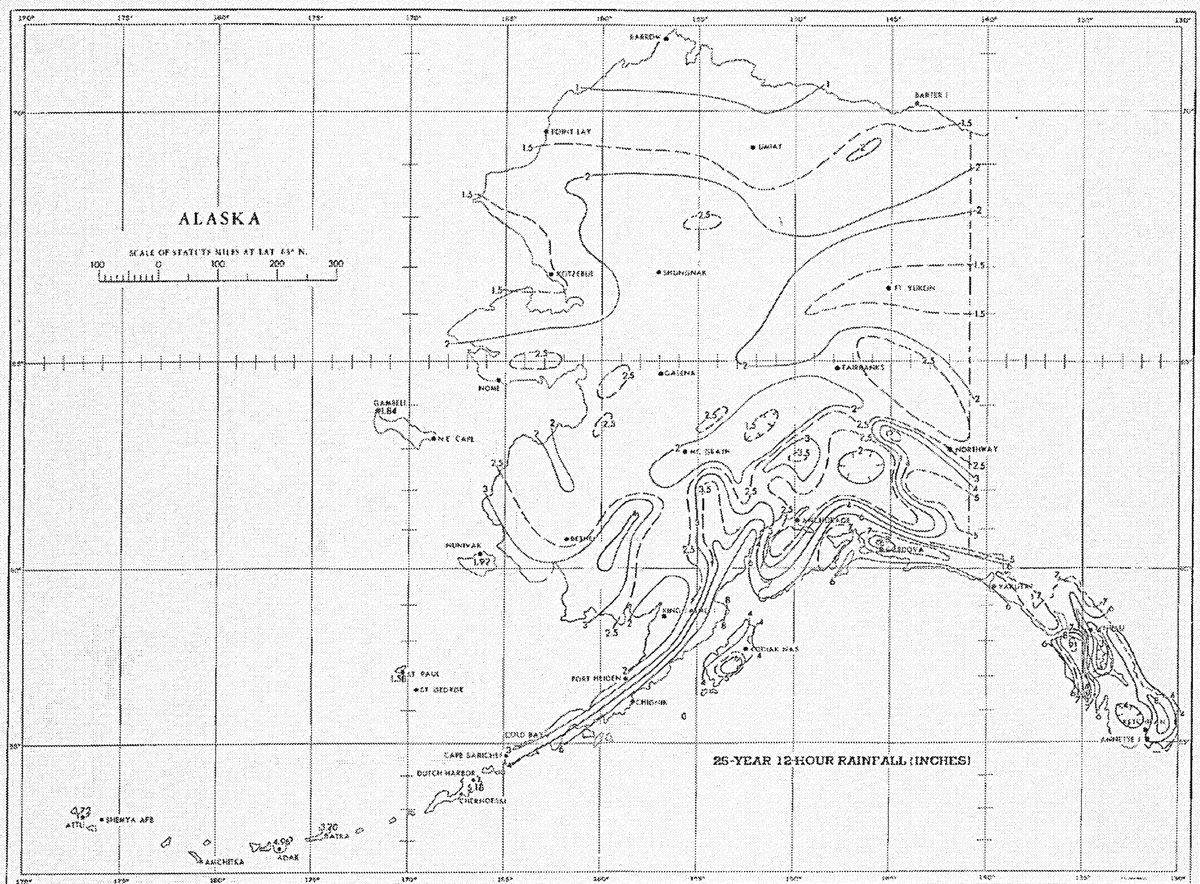


FIGURE 3-50.—25-yr. 12-hr. rainfall (in.).

50 y 12

2 Btn

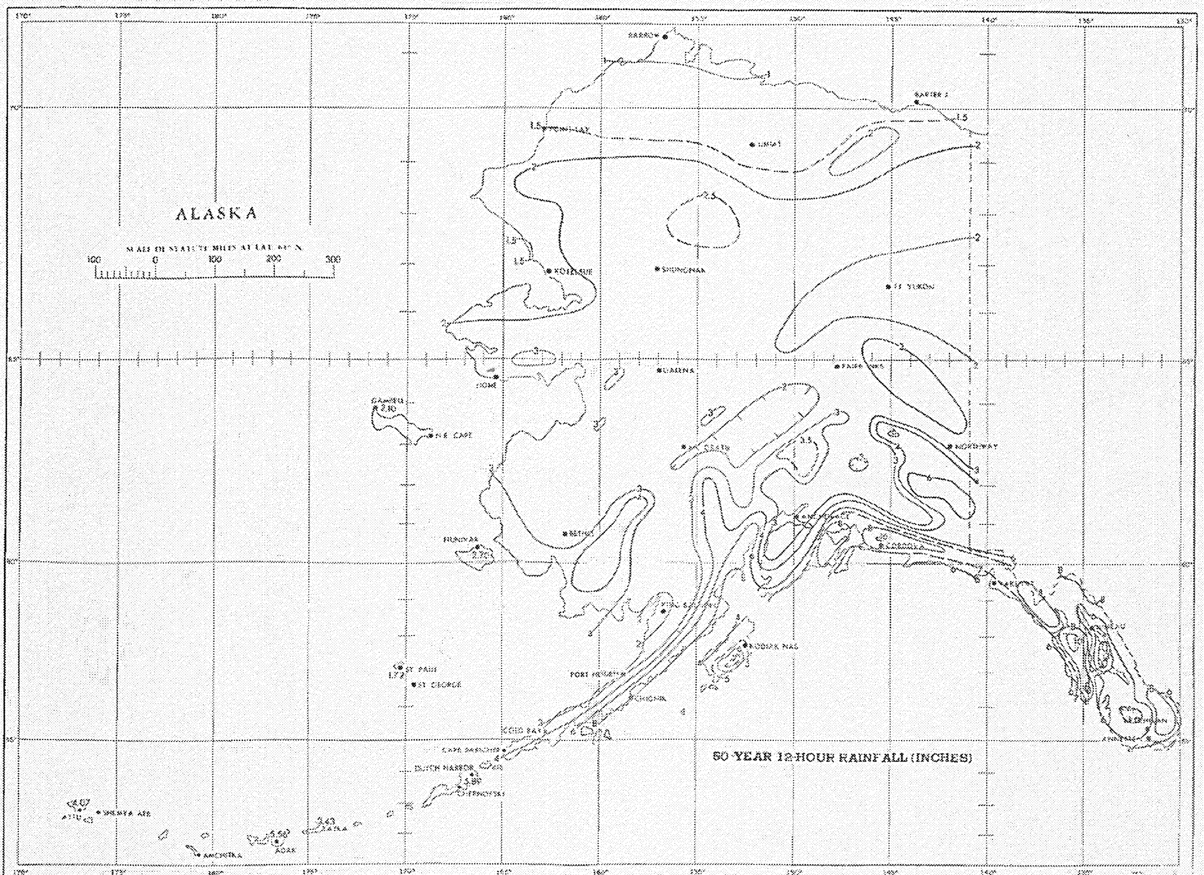


FIGURE 3-51.—50-yr. 12-hr. rainfall (in.).

100y 12h

2 Rock
3 Murrah — right on line

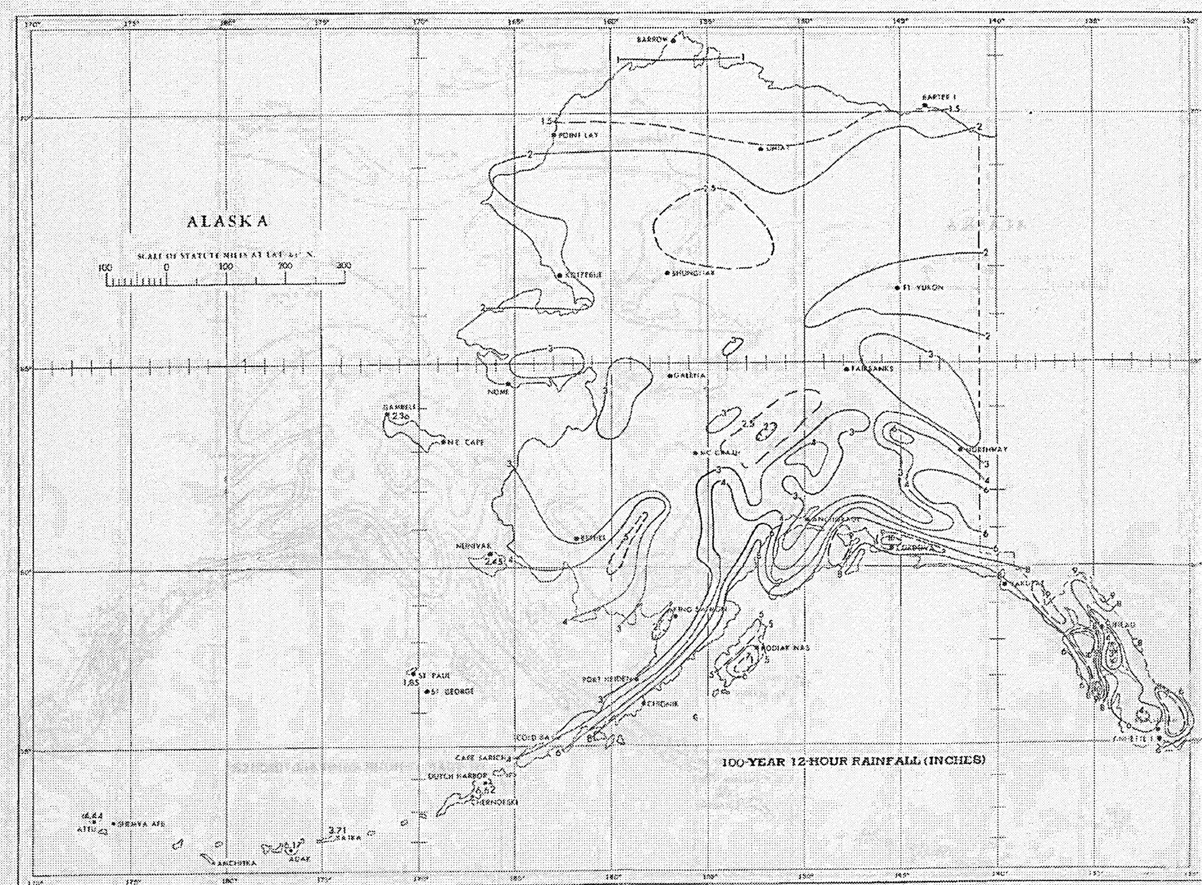


FIGURE 3-52.—100-yr. 12-hr. rainfall (in.).

1y244

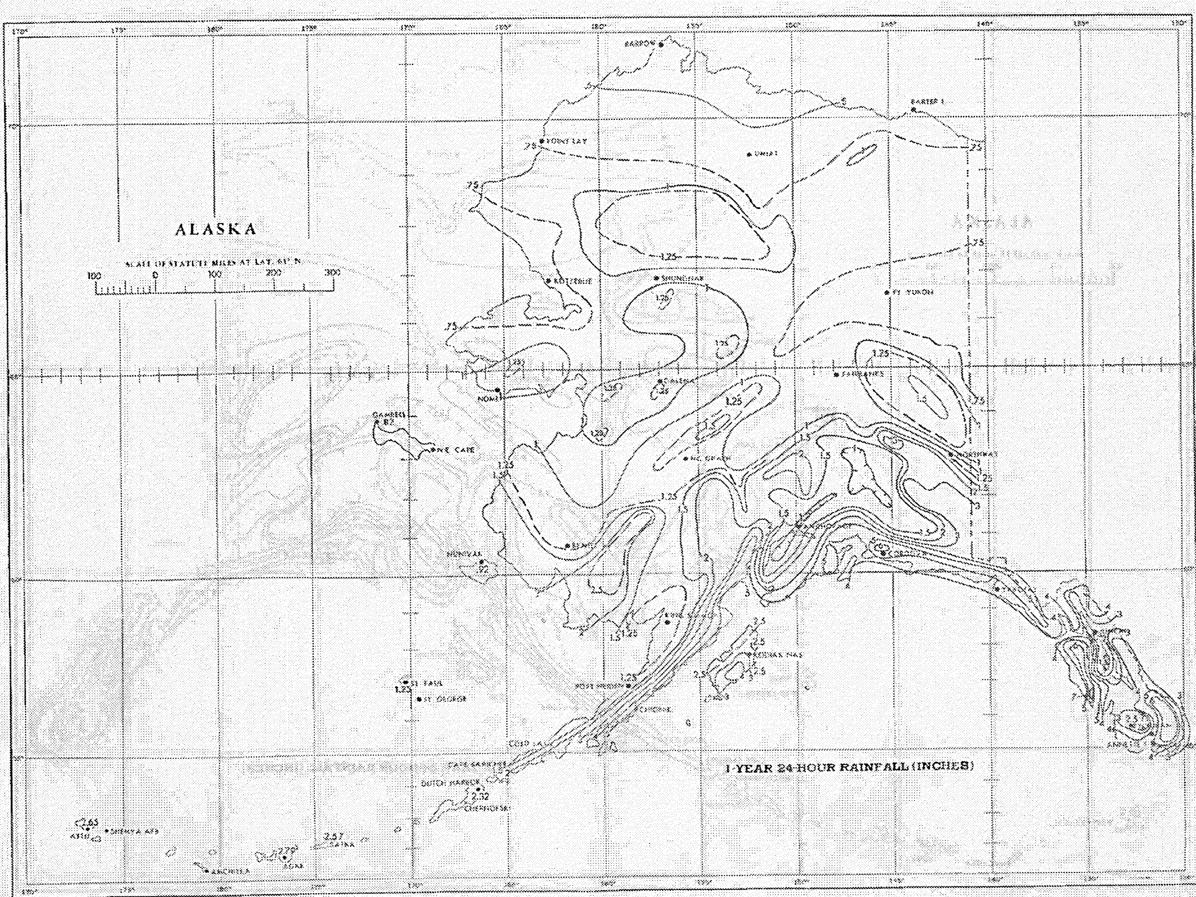


FIGURE 3-53.—1-yr. 24-hr. rainfall (in.).

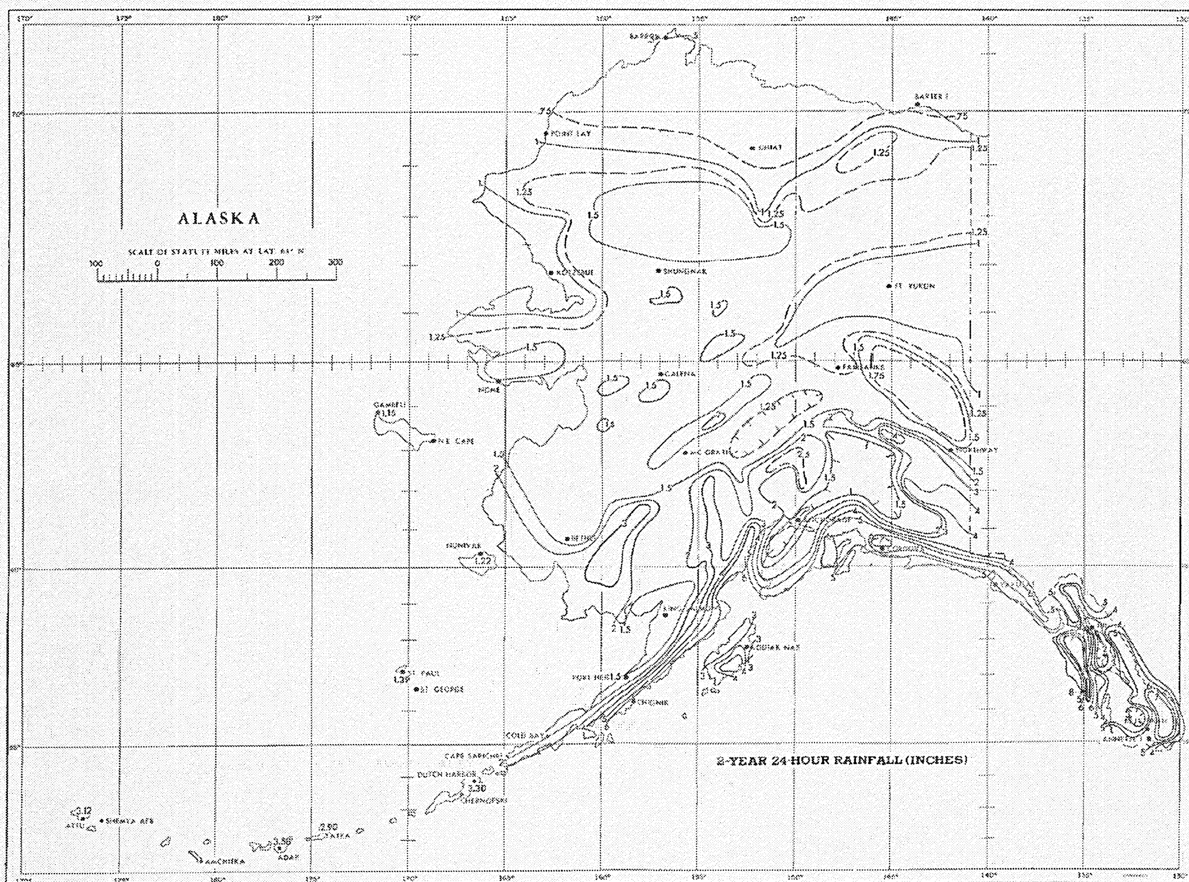


FIGURE 3-54.—2-yr. 24-hr. rainfall (in.).

5y 24h

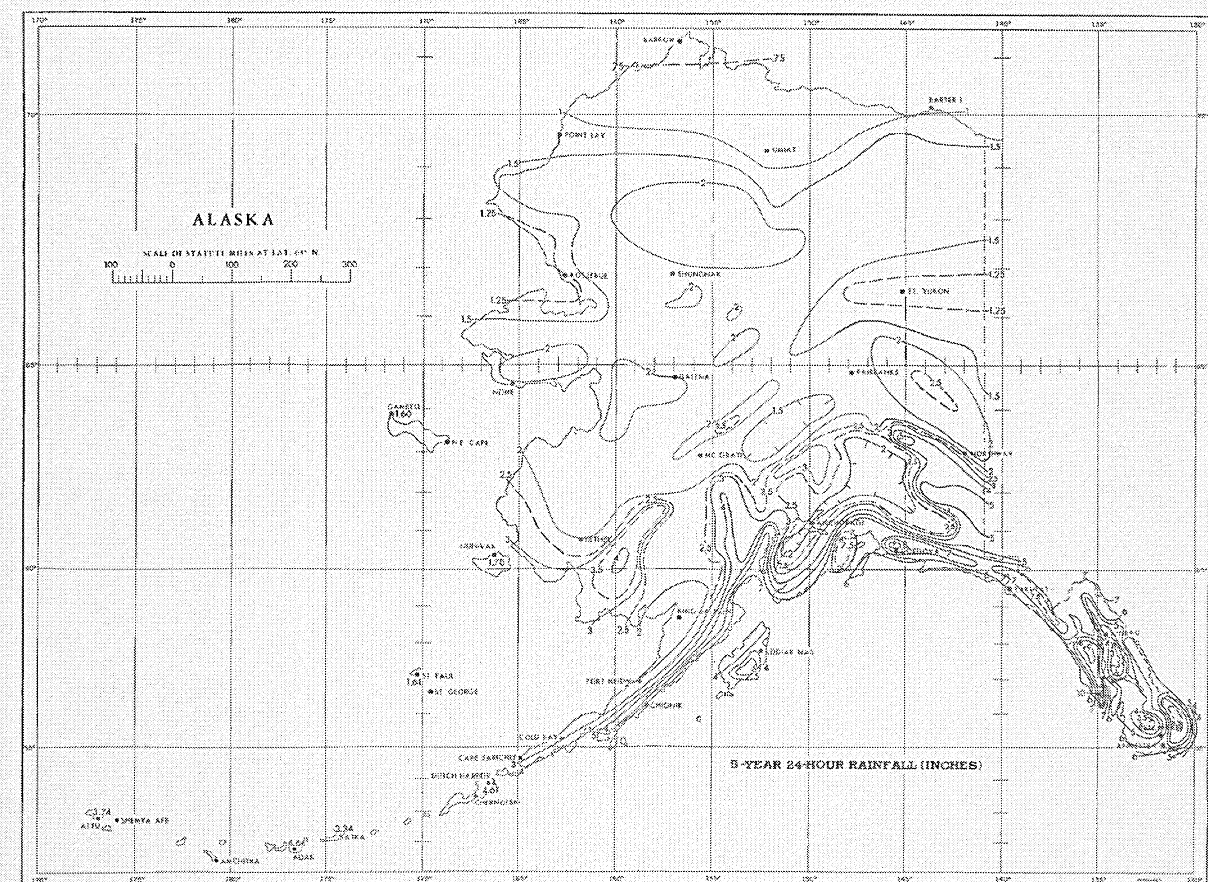


FIGURE 3-55.—5-yr. 24-hr. rainfall (in.).

10y 24h

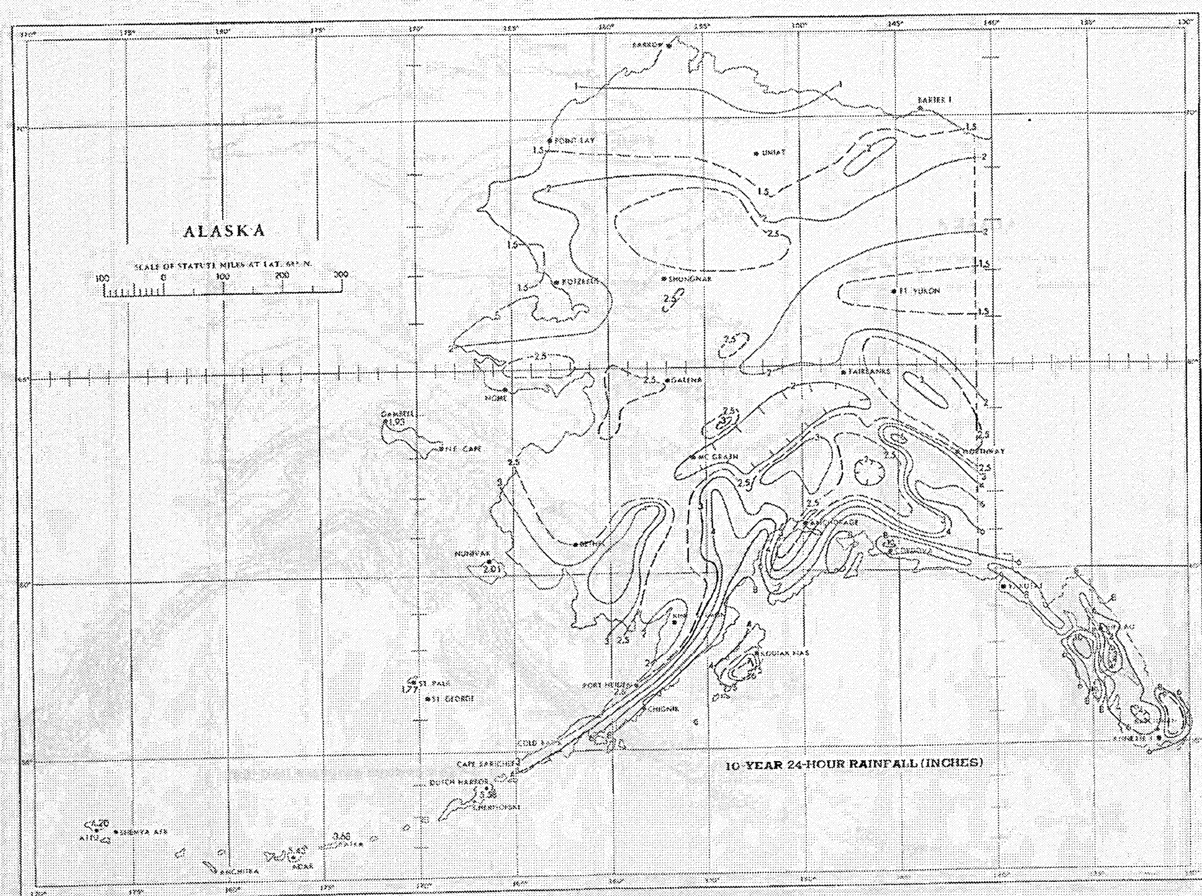


FIGURE 3-56.—10-yr. 24-hr. rainfall (in.).

25 y 24 h

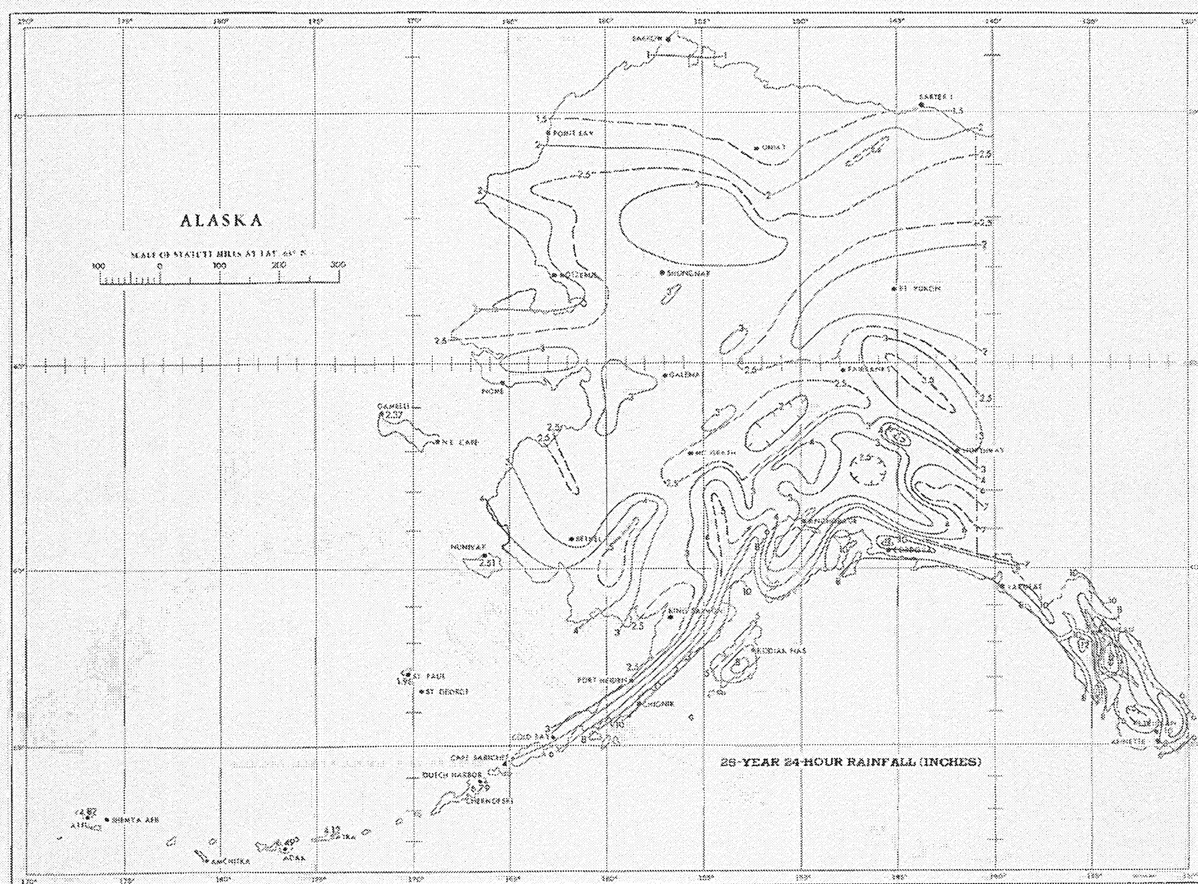


FIGURE 3-57.—25-yr. 24-hr. rainfall (in.).

3 Both

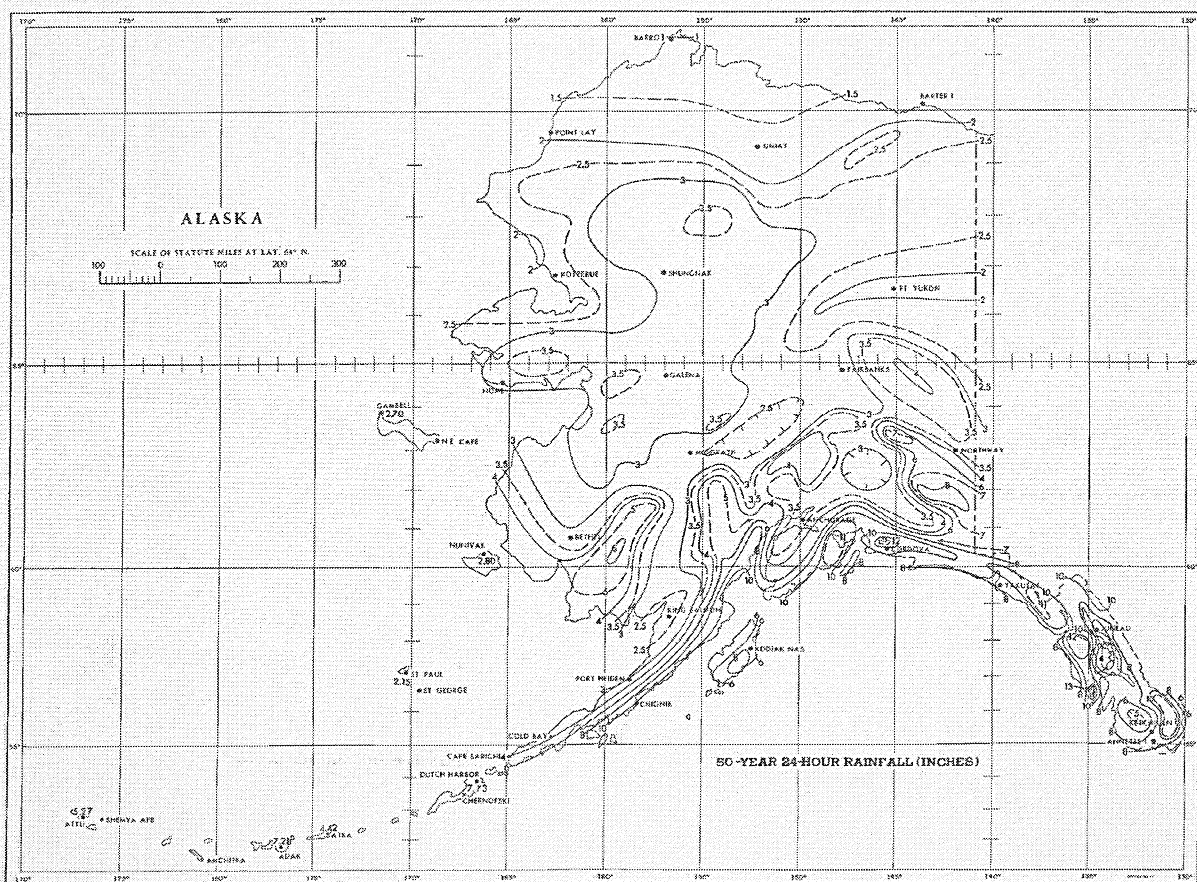


FIGURE 3-58.—50-yr. 24-hr. rainfall (in.).

100y 24h

Rock 3
Hurrah 3.5

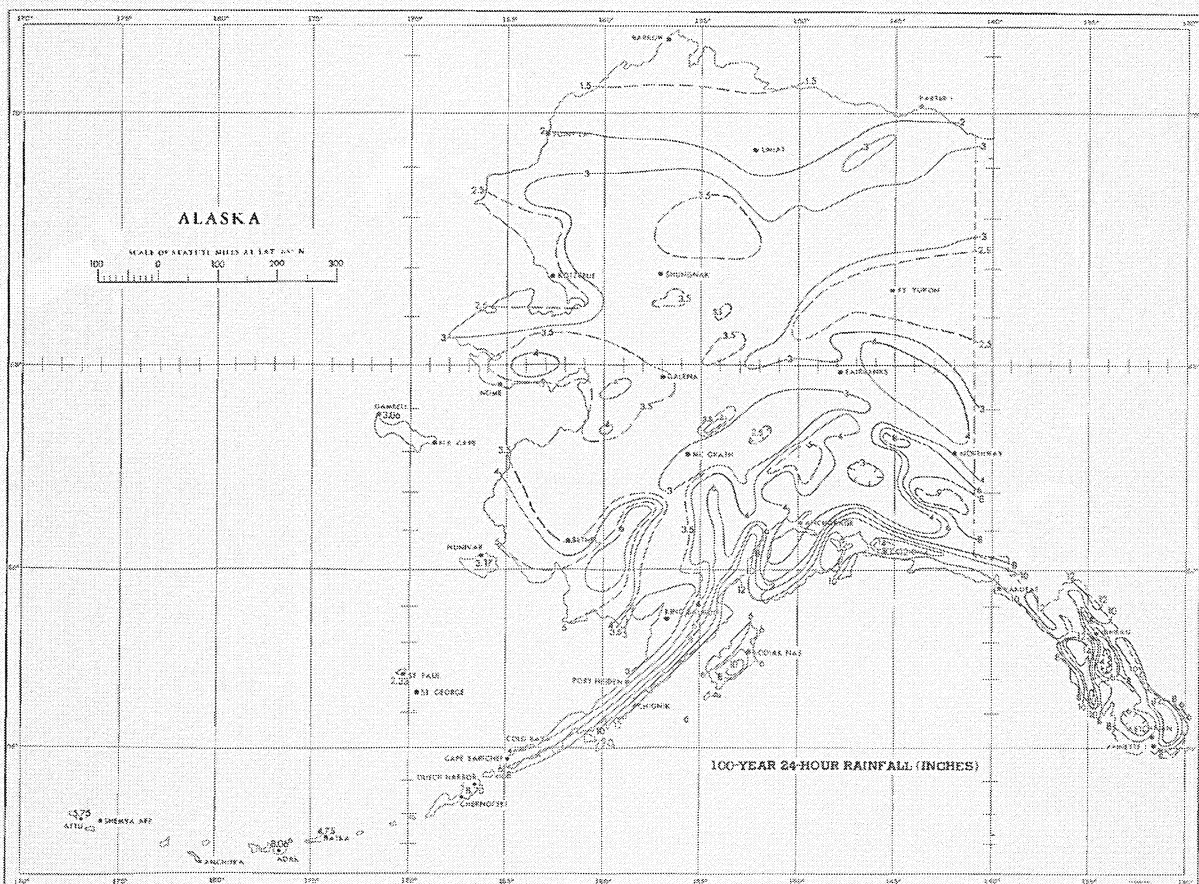


FIGURE 3-59.—100-yr. 24-hr. rainfall (in.).

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APPENDIX C:

Probable Maximum Precipitation Calculations

The probable maximum precipitation (PMP) was calculated according to the Hershifield Method:

$$X_m = \overline{X}_n + K_m S_n$$

where: X_m = maximum observed rainfall, or PMP (mm)
$\overline{X}_n$ = mean of series of annual maximum precipitation values (mm)
K_m = statistical adjustment factor
S_n = standard deviation of annual maximum precipitation values (mm)

The quantities $\overline{X}_n$ and S_n were determined from a 56 year record of annual maximum precipitation values, and adjusted for outliers according to the Hershfield Method.

The value of K_m was determined based upon the rainfall duration (24 hours) and the mean of the annual maximum precipitation series.

APPENDIX D:

Evaporation Calculations

Rock Creek Project Evaporation Calculations

Combined Aerodynamic and Energy Balance Method: Penman and Thornthwaite
Chow, Maidment and Mays p. 88

$$E = \frac{\Delta}{\Delta + \gamma} E_r + \frac{\gamma}{\Delta + \gamma} E_a$$

E in mm/day	Total evaporation
E_r in mm/day	Evaporation rate by energy balance
E_a in mm/day	Evaporation rate by aerodynamic method

$$\Delta = \frac{4098 e_s}{(237.3 + T)^2}$$

$$e_s = 611 \exp\left(\frac{17.27 T}{237.3 + T}\right)$$

$$\gamma = \frac{C_p K_h p}{0.622 l_v K_w}$$

$$l_v = 2.501 \times 10^6 - 2370 T$$

$$E_r = \frac{R_n}{l_v \rho_w}$$

$$E_a = B(e_{as} - e_a)$$

$$R_h = \frac{e}{e_s}$$

$$B = \frac{0.622 k^2 \rho_a u_2}{p \rho_w \left[\ln\left(z_2 / z_0\right)\right]^2}$$

Δ in Pa/ºC	Gradient of the saturated vapor pressure curve at given air temperature
γ in Pa/ºC	Psychrometric constant
e_s in Pa	Saturation vapor pressure over a water surface
T in C	Temperature
T in C	Temperature
C_p=1005 J/kg*K	Specific heat at constant pressure
p in Pa	Atmospheric pressure
K_h/K_w = 1	Ratio of heat diffusivity to vapor diffusivity
T in C	Temperature
R_n in W/m^2	Net radiation flux
l_v in J/kg	Latent heat of vaporization
ρ_w in kg/m^3	Water density at given temperature
e_a in Pa	Ambient vapor pressure
B in m/Pa*s	Vapor transfer coefficient
k (dimensionless)	Von Karman constant = 0.4
ρ_a in kg/m^3	Air density at given temperature
u in m/s	Wind speed
p in Pa	Atmospheric pressure
ρ_w in kg/m^3	Water density at given temperature
z_2 in m	Height of wind speed measurement
z_0 in m	Roughness height (over water = 0.03 cm)

** **NOTE**: For temp <0, no evaporation was assumed,
see sublimation calculations

APPENDIX E:

Evapotranspiration Calculations

Evapotranspiration Calculations

Combined Aerodynamic and Energy Balance Method: Penman and Thornthwaite
Chow, Maidment and Mays p. 88

$$E = \frac{\Delta}{\Delta + \gamma} E_r + \frac{\gamma}{\Delta + \gamma} E_a$$

$$\Delta = \frac{4098\ e_s}{(237.3 + T)^2}$$

$$e_s = 611\ \exp\left(\frac{17.27\,T}{237.3 + T}\right)$$

$$\gamma = \frac{C_p K_h p}{0.622\ l_v K_w}$$

$$l_v = 2.501 \times 10^6 - 2370\ T$$

$$E_r = \frac{R_n}{l_v \rho_w}$$

$$E_a = B(e_{as} - e_a)$$

$$R_h = \frac{e}{e_s}$$

$$B = 0.0027\left(1 + \frac{u}{100}\right)$$

** **NOTE**: For temp <0, no evaporation was assumed, see sublimation calculations

E in mm/day	Total evaporation
E_r in mm/day	Evaporation rate by energy balance
E_a in mm/day	Evaporation rate by aerodynamic method
Δ in Pa/ºC	Gradient of the saturated vapor pressure curve at given air temperature
γ in Pa/ºC	Psychrometric constant
e_s in Pa	Saturation vapor pressure over a water surface
T in C	Temperature
T in C	Temperature
C_p=1005 J/kg*K	Specific heat at constant pressure
p in Pa	Atmospheric pressure
$K_h/K_w = 1$	Ratio of heat diffusivity to vapor diffusivity
T in C	Temperature
R_n in W/m^2	Net radiation flux
l_v in J/kg	Latent heat of vaporization
ρ_w in kg/m^3	Water density at given temperature
e_a in Pa	Ambient vapor pressure
B in mm/Pa*day	Vapor transport coefficient *** **Adjusted for EVAPOTRANSPIRATION from LAND**
u in km/day	24-h wind run in km/day at 2 m elev

APPENDIX F:

Snow Sublimation Calculations

Snow Sublimation Calculations for November, December, January, February, and March

(months with more than half of all days below freezing temperatures)

Empirical formula for rate of surface (not intercepted or blowing) snow sublimation as presented by Gelfan:

$$E_s = (0.18 + 0.98u)(e_{si} - e_a)$$

E_s in mm/day	Snow sublimation
u in m/s	Wind velocity at 10-m height
e_s in mbar	Saturated vapor pressure over ice..... To convert vapor pressure over water to the equivalent vapor pressure
e_a in mbar	Air vapor pressure over ice, use US Weather Bureau Method presented by Bosen:

$$\frac{e_{si}}{e_s} \cong 1 + 0.00972T + 0.000042T^2$$

e_{si} : saturation vapor pressure over ice
e_s : saturation vapor pressure over water calcs
T in C

****NOTE**: Elevation of wind speed data was not indicated; Same wind speed data are used in sublimation and evaporation calculations

Table A1. Nome Snow-Water Equivalents

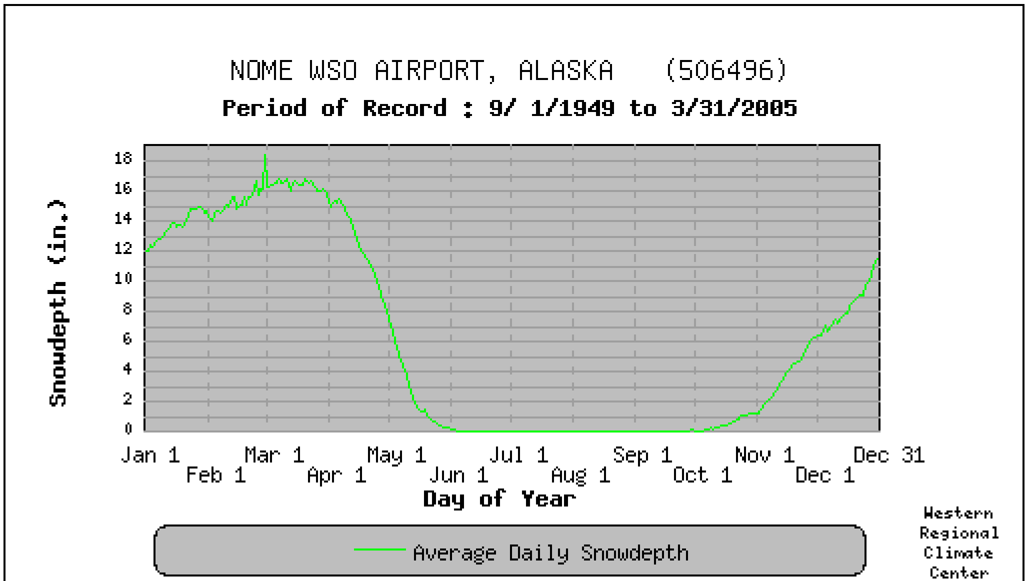
Month	Calculated Water % of Snow
November	9.91
December	8.71
January	9.26
February	8.67
March	8.59

APPENDIX G:

Snow Melt

NOME WSO AIRPORT, ALASKA

Period Of Record - Daily Snowdepth Average



- Average of all daily snowdepth recorded for the day of the year.

Available at: http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?aknome